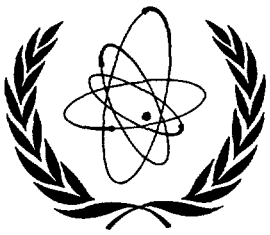

International Atomic Energy Agency

PROGRESS IN PEACEFUL APPLICATIONS OF NUCLEAR ENERGY DURING THE YEAR 1967/68

Statements by Member States

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PROGRESS IN PEACEFUL APPLICATIONS OF NUCLEAR ENERGY DURING THE YEAR 1967/68

Statements by Member States

This booklet contains the 30 statements on the progress made during the year 1967-68 in peaceful applications of nuclear energy which Governments of Member States had communicated to the Director General by the end of November 1968[1].

1) The Government of the Netherlands has informed the Director General that it would propose to communicate a statement next year in respect of the period 1968/69.

1. AUSTRIA

The Reactor Centre at Seibersdorf in 1967

1. As in previous years, some 30 million Austrian schillings were available in 1967 for the purpose of modernizing and supplementing the scientific facilities of the Austrian Research and Reactor Centre at Seibersdorf. The total of investments has thus reached the 300 million schilling level. This remarkable amount, however, is still only a small part of what has so far been made available, for instance, in Switzerland or Sweden. By restricting activities to a few vital research tasks it was possible to achieve results that come up to the international standard, though the running costs did not exceed those of the previous year.

2. What is often considered a remarkable success is the combination of basic and applied research as it is being carried out at Seibersdorf. One hundred and two of the most outstanding students of Austrian universities majoring in the fields of technology and science use the facilities at the Centre for work on their diplomas and Doctor of Philosophy theses. On the other hand, income from contract research — in particular from isotope application in industry — amounted to over eight million Austrian schillings in the past year.

3. The quality of a research organization may be judged by two yardsticks. The first is the number and the value of its publications. So far the scientists of the Centre have published the notable total of 899 papers, mainly in German, English and French. Nearly all of these have appeared in well-known scientific books or journals. The second yardstick is the volume of research for which payment has been duly made. The patent and licence situation, too, may give a hint as to the research and development activities. It is to be noted in this connection that the utilization of patents and licences is specifically provided for in the charter of the Österreichische Studiengesellschaft für Atomenergie Ges.m.b.H. (SGAE), which operates the Centre.

4. We have now reached the stage of utilizing results from research. By now SGAE holds a total of 112 Austrian patents in force, mainly in the fields of isotope application and power reactors, and 67 applications are pending. Furthermore, 59 patents have been awarded in foreign countries and 70 are pending, mainly in the United States of America, the United Kingdom of Great Britain and Northern Ireland, the Federal Republic of Germany and France. This guarantees that interested foreign parties that have a large sphere of influence may become active in Austria only if an agreement can be reached, as well as a co-operation and sharing of work acceptable to Austrian industry. The number of patents granted is telling evidence of the fact that the long-range and methodical help which Austrian industry has given to SGAE is now beginning to bear fruit, to be harvested by the member organizations of SGAE as well as by industry as a whole.

5. Due to the fact that SGAE holds such a remarkable number of domestic patents, it has been possible to create a basis for obtaining the right to use the techniques and patents of other countries by way of exchange. In the following paragraphs a few examples are given of the utilization of domestic patents and other "know-how".

6. The Centre's Institute of Electronics has developed new amplifiers and single-channel discriminators. Since no Austrian enterprise seemed to be interested in producing these devices, licence contracts for three types were concluded with a German firm in Munich. Further licences are about to be granted. The German firm plans to manufacture a complete range of nuclear measuring devices following the Seibersdorf prototypes. Generally, the Centre offers the total "know-how" and a prototype device with all the diagrams and lists of components, and the licensee pays a non-recurring sum as well as a licence fee of about 3-5% of the selling price for all devices sold. The licensee usually assumes a liability to sell a certain minimum number of devices each year.

7. The Institute of Health Physics and the Institute of Chemistry have joined forces with the result that Austrian patent number 257.858 entitled "Procedure for the Manufacture of an Argentiferous Glass which is Sensitive to both Radioactive Radiation and X-rays" has been granted. This invention will replace the film dosimeters used so far. In this matter negotiations with an Austrian firm concerning the acquisition of the patent and the manufacture of the phosphate glass dosimeter are near completion. Regarding the production of a read-out device belonging to it, which is also protected by patent, there have been negotiations with four Austrian and two German firms which have finally culminated in a preliminary contract. This example illustrates clearly that new

and economically interesting achievements can be produced by employing even small funds, as long as good ideas are forthcoming.

8. The frequently cited Compton spectrometer is the patent that is the most interesting scientifically and internationally speaking. In the economic field, too, it is likely to achieve a full success. The apparatus was recently tested with power reactor fuel at Windscale, England, and has proved very efficient. The device was also on exhibit in the Austrian Pavilion at the World Fair in Montreal.

9. Utilization of the "know-how" is also guaranteed in the case of the Seibersdorf mass separator, since an American firm has submitted a letter of intent with a view to a purchase order. The production of two such devices at a total cost amounting to 15 million Austrian schillings is under discussion. The final placing of the order, however, is connected with guarantees which have yet to be discussed. In case of the actual utilization of these products, several member organizations of SGAE would take part.

10. The Industrial Advice and Isotope Application Section is making steady headway. In one way or another this Section of the Centre has been of some help to almost every one of the 53 industrial member organizations. This rather small Section has obtained five Austrian and nine foreign patents. Even beyond the Austrian border the examination of rim lubrication of the wheels of train coaches with the help of radioactive gold has found recognition. The Agency has found this application of considerable interest, and many European railway companies have introduced the technique, benefiting from Austrian experience of its use.

11. The ASTRA-Reactor Institute has been able to exploit several developments internationally. These include in particular a high-temperature irradiation capsule developed for testing coated particle reactor fuel. The development of the capsule was carried out mainly at Seibersdorf in co-operation with a member organization. Besides other industrial irradiation facilities, a unit for the irradiation of biological material with fast neutrons has found international recognition. Co-operating initially with the Agency, SGAE designed the irradiation unit which was finally built by an Austrian firm. Copies of this unit have in the meantime been built for India, the Philippines, Thailand and the United States. There are also orders from Bulgaria and China.

12. Of equal importance are the Institute of Chemistry and the Institute of Metallurgy which have made great achievements in the development of new nuclear fuels since the very start-up of the Centre. Originally participants in the international Dragon High-Temperature Reactor Project, these Institutes now co-operate mainly with the Federal Republic of Germany and the United Kingdom. Four Austrian patents, and nine patent applications which are at the publishing stage, have brought us the Dragon, the German and the American orders. The resulting research contracts have led to further applications for patents; these will, however, belong to the authorities awarding the contracts, though in all cases SGAE will hold the full rights for Austria. By the end of 1967 the two Institutes had received almost 20 million Austrian schillings as income from successful research work.

13. In the field of isotope production the Institute of Chemistry holds two patents, one of which covers an important procedure for the manufacture of iodine-131 from telluric acid. In Austria this isotope is often used for medical as well as industrial purposes. Research results from the Institute may be vital for future activities of the Austrian wood and synthetics industries, since it is now possible to produce technically interesting combinations of wood and synthetics.

14. The Institute of Reactor Technology has, in the short period of its existence, followed a particularly industry-minded line of development. Two major projects in co-operation with a member organization involving expenditures of several million Austrian schillings testify to this fact. The sodium loop and the development of a plant for the disposal of radioactive waste water are perfect examples of passing on "know-how" by the Centre to one of SGAE's industrial member organizations.

2. BELGIUM

Developments in the Field of Nuclear Energy in 1967/68

RESEARCH AND SUPPORT PROGRAMMES

1. In 1967 the Belgian Government drew up a five-year programme covering the period 1968-1972. This programme follows on the 1965-67 three-year plan and relates to the following main subjects:

(a) Fast reactors;

(b) Dry reprocessing of fuel:

(c) Proven reactors;

(d) Basic research;

(e) Other research programmes;

(f) Operation of the high-flux materials testing reactor (BR-2).

Fast reactors

2. The development of fast reactors is given top priority in the coming five-year plan. The work is to be carried out under a tripartite collaboration programme approved by the Federal German, Netherlands, and Belgian Governments during 1967. This programme provides, first, for the joint construction of a 300 MW(e) prototype facility which is to be operational by 1974, and, secondly, for continued co-operation on the industrial level with a view to the manufacture and sale of commercial fast-breeder reactors.

3. Construction of the planned prototype facility will be accompanied by a research and development programme designed to make it possible to apply the characteristics of the prototype by extrapolation to industrial power plants and thereby improve their performance. This programme, the major part of which will be carried out by the Nuclear Energy Research Centre (CEN), deals particularly with sodium technology, the development of new cladding materials, the production of advanced oxide and carbide fuels, reactor physics, and the design of new equipment. It will also involve a large number of irradiation experiments in the BR-2 as well as in other reactors manufactured abroad.

Dry reprocessing of fuel

4. In addition to conventional reprocessing techniques using organic solvents, a number of countries have been interested for some years in an original processing method which entails separating the uranium, plutonium and fission products by means of halogen reagents, in particular chlorine and fluorine trifluoride.

5. This method, which has been tried out by the CEN with industrial backing, appears particularly suitable for fast-reactor fuels that need to be reprocessed at very high burnup rates, for which reprocessing facilities of other types are not very suitable.

6. The coming five-year period will be chiefly devoted to further investigation of the conditions in which existing facilities can be operated, continuation of basic research, the development of certain equipment and the conceptual study of a commercial pilot plant. Detailed study and construction of the pilot plant are scheduled for around 1974.

Proven reactors

7. The research planned by Belgium in this field primarily concerns the improvement of pressurized water reactors and the development of more advanced fuels. The research involves the design of new equipment, the study and calculation of reactor cores, and also the improvement of techniques for industrial fuel fabrication, particularly in the case of fuels intended for the first big Belgian power stations. In addition, efforts will be concentrated on plutonium fuels with a view to their possible recycling in thermal reactors.

8. An important part of this programme is the design and construction of improved cores for the BR-3 reactor at Mol (the first Belgian nuclear power station equipped with an 11.5 MW(e) pressurized water reactor). The intention is that these cores should make it possible to test the techniques for fabricating Zircaloy-clad fuels and to make statistical assessments of pins containing plutonium or burnable poisons.

Basic research

9. This research is being undertaken within the framework of international bodies, such as the European Organization for Nuclear Research (CERN), at the same time as by university laboratories and the CEN. It concerns high-energy physics (in conjunction with the experiments conducted by CERN in Geneva), low-energy physics, nuclear chemistry, solid-state physics, neutron physics and radiation biology. Those studies, which require special equipment such as large accelerators, reactors or safety equipment are carried out either by the CEN at Mol or in collaboration with CERN. As for the universities, they play an important part in theoretical physics, low-energy physics and nuclear chemistry.

Other research programmes

10. These programmes relate to research in the field of safety and waste disposal, exploratory studies on chemical metallurgy and reactor physics and work on the use of radioisotopes. For the most part, they are carried out by the CEN at Mol.

Operation of the BR-2 reactor

11. Until the end of 1967 the BR-2 test reactor was operated jointly by the CEN and EURATOM. It has already been used for a large number of irradiation experiments commissioned by Belgian and foreign clients on fissionable and structural materials.

12. In future the reactor will be jointly operated by the German research centre Gesellschaft für Kernforschung, and the CEN, primarily for irradiation experiments under the fast reactor programme. This provides for the construction of several large-size loops that will make it possible to irradiate sodium-cooled reactor fuels under simulated conditions.

Budgetary matters

13. In 1968 the nuclear energy budget for Belgium will be about B.Fr. 1400 million, or more than an 11% increase against 1967. Of this total 37% pertains to Belgian participation in international bodies and 63% to the financing of activities on a national level.

14. In the programme as a whole, basic research accounts for 25%, technological research 50%, and public services and support activities 25%. On the national level the CEN absorbs close to 60% of the funds available, with industry receiving 28% and university laboratories 12%.

NUCLEAR POWER STATIONS

BR-3/Vulcan Power Station

15. The CEN's 11.5 MW(e) BR-3 pilot power station was operating commercially with a Vulcan core over virtually the whole of 1967. The overall load factor on 31 December 1967 was 93.5%, while the availability of the reactor had risen to 98.2% by the same date; this can be considered a remarkable achievement.

16. In 1967 the net output of electricity supplied to the network rose to 85 million kWh. In March and July of the same year a series of physical measurements was undertaken, which included, first and foremost, analysis of the dynamic behaviour of the plant during unloading at various power levels.

17. Full-power operation of the reactor was continued in 1968 until 22 April, with a break for a few days while a third series of experiments was undertaken. By the end of April some of the fuel passed the maximum scheduled burnup rate of 40 000 MWd/t U; the objective of the first phase in the BR-3/Vulcan experiments was thereby attained.

18. Since that time, the core has been used for an endurance test programme involving cycling of the reactor power. On 13 June 1968, the mean and maximum burnup rates for the fuel were 20 000 and 44 000 MWd/t U respectively.

19. The objective of the second experimental phase now in progress, which is to reach a maximum burnup of about 50 000 MWd/t U, will, it is expected, be attained round about September 1968.

Ardennes Nuclear Power Station at Chooz

20. The contract between the Société d'énergie nucléaire franco-belge des Ardennes (SENA) and the AFW building consortium for construction of the Ardennes Nuclear Power Station at Chooz in France was signed on 25 September 1961. The AFW consortium is composed of the Charleroi Electrical Engineering Works (ACEC), the Cockerill Ougrée-Providence Company, and the Nuclear Metallurgy and Mechanical Engineering Company (MMN) on the Belgian side, the FRAMATOME Company on the French side and the Westinghouse Electric Corporation on behalf of the United States of America. Except for the first reactor core, manufacture of all equipment was shared equally between Belgium and France.

21. The Ardennes Nuclear Power Station, which has a capacity of 288 MW(e) when coupled to the turbine (gross output) stands on the river Meuse,

in direct proximity to the French-Belgian border. It is fitted with a pressurized water reactor using slightly enriched uranium as fuel and pressurized light water (140 kg/cm^2) as moderator and coolant.

22. SENA selected a duplex type of installation for the Ardennes power station, which means that the nuclear steam generator is located underground, while the turbo-alternator unit and its ancillaries are housed in a conventional-style building at ground level.

23. The decision to build the power station fulfilled two purposes. The first was to provide the Belgian and French building consortium with an opportunity of adjusting to a completely new technique, and the second was to enable electric utilities to familiarize themselves with the operation of high-power nuclear power stations and to train operating personnel.

24. Assembly of the reactor was completed during 1966 and the reactor first went critical on 18 October of the same year.

25. The reactor then underwent nuclear tests accompanied by a series of routine tests on the conventional section of the power station. The latter was connected to the French and Belgian power networks on 3 April 1967. It had generated more than 630 million kWh by the end of January 1968, when an incident affecting the parts inside the reactor tank occurred. The dismantling of the reactor, removal of the fuel elements and inspection of the area where the incident occurred lasted several weeks. The heat exchangers in particular will have to undergo certain repairs. The exact cause of the incident, as well as the remedial action needed, are still under investigation. Resumption of operations at the power station is not expected until the end of 1968.

Doel and Tihange Power Stations

26. Belgian and French electric utilities have decided to continue their collaboration and to build a power station with a 750 MW(e) pressurized water reactor at Tihange in Belgium, due to be put into operation in 1974/75. The Belgian utilities also plan to erect a twin-reactor power station with two pressurized water reactors, each with an output of 375 MW(e), at Doel near Antwerp. The first of these two reactors will be started up in 1972-73, and the second in 1975-76. To undertake this work Belgian engineers have decided to form a Belgian consortium comprising ACEC, Belgonucléaire, Cockerill Ougrée-Providence and MMN. The final order for the two stations is expected to be placed before the end of 1968.

3. BRAZIL

Advances in the Peaceful Uses of Nuclear Energy in 1967/68

1. The Government of Brazil, in order to influence the direction of nuclear energy development in the country, has issued guidelines on national nuclear energy policy in which it defines the responsibilities of various bodies in the Federal Administration.

2. As a result of the efforts of the Ministry of Mines and Power, an agreement was reached between the National Nuclear Energy Commission (CNEN) and Electrobrás concerning the design and utilization of nuclear plants for the production of electric power. These two bodies have already started work on implementing the Government's decision to build a 500-MW(e) power reactor in the Central South Region. This represents the first step in a programme which provides for the construction and operation of other nuclear power plants as well.

3. CNEN's budget for 1968 rose by 84% from 13 215 700 to 24 267 000 cruzeiros, thereby affording an opportunity, as far as physical facilities are concerned, for the concentration of all of CNEN's sections in a building of its own, and also for the construction of the chemical engineering buildings of the Atomic Energy Institute of São Paulo, the administration building and auditorium of the Nuclear Engineering Institute on Fundão Island and a building for the Thorium Group of the Belo Horizonte Institute of Research on Radioactivity. It is also worth mentioning that CNEN's budget for 1969 will be more than twice as large as that approved for 1968.

4. With these financial resources at its disposal, CNEN can, as part of its many activities relating to exploration for uranium, contract for aerial pro-

spection services along the western edge of the Piauí-Maranhão basin, covering an area of 37 000 km² and including part of the States of Goiás, Maranhão and Pará. It will also be able to set up a North-East District, with headquarters at Fortalieza, for the purpose of carrying on prospection for uranium in the Piauí-Maranhão basin, and to start work on opening up a mine gallery in Poços de Caldas. This will be the first such gallery in Brazil and is intended for use in the extraction of ore on a pilot scale. The purpose of this work is to use Brazilian technical resources in the exploration of the uranium ore found.

5. This upsurge in and expansion of CNEN's activities have not been limited to first priority activities: the work of the Centre for Nuclear Energy Applications in Agriculture (which is part of the Luiz de Queiróz Advanced School of Agriculture) has now been integrated with the national nuclear energy programme. Preparations have nearly been completed for a similar arrangement with the Biophysics Institute of the Federal University of Rio de Janeiro, in the interest of an intensification of health physics work.

6. CNEN is organizing a joint corporation, known as COMAMBRA, for the purpose of exploring the country's nuclear ore resources. This organization will combine the present Monazite Production Administration and the existing Brazilian plants engaged in the extraction and working of monazite sands.

7. A research programme which is now being developed involves an expansion of work on nuclear physics, reactor physics, nuclear chemistry, nuclear materials, nuclear medicine and radioisotope applications.

8. As a result of the unremitting efforts of the Brazilian Government in dealing with problems of nuclear energy development, Brazil has won international recognition, as evidenced not only by the mutual assistance agreements which it has concluded with other countries, but also by the assistance which it has received for research and training. In 1967, it was a major recipient of Agency assistance, representing a value of US $185 000. Among the projects benefiting from the Agency's technical assistance, mention should be made of the work of a group of experts selected by the Agency who, in collaboration with engineers from Electrobrás and CNEN, have carried out studies relating to the incorporation of nuclear power plants into the country's electrical power systems, especially in the Central South Region.

4. CANADA

Progress in the Peaceful Applications of Nuclear Energy during 1967/68

1. There has been considerable progress and expansion in the Canadian nuclear and uranium mining industries during the past year. In the nuclear power programme, the most important development was the announcement by the Hydro Electric Power Commission of Ontario (Ontario Hydro) that it expects to make a major new commitment in Canadian heavy water reactors before the year's end. This new development would involve some 3000 MW(e) of nuclear capacity and would envisage the use of generating units of 750 MW(e) each. Not only would this represent an important increase over the size of the four 540-MW(e) units chosen for their Pickering nuclear power station, but also a re-affirmation of this major utility's confidence in the natural uranium fuelled, heavy water moderated reactor system developed by Atomic Energy of Canada, Limited (AECL) and known as the CANDU system. With Pickering, Ontario Hydro would have 5000 MW(e) of nuclear capacity within its system and would become one of the world's largest producers of electricity from nuclear energy.

2. Confidence in the CANDU system has sprung from the operation of both Douglas Point nuclear power station and the Nuclear Power Demonstration plant (NPD), both of which are being operated at full power. It will be recalled that Douglas Point began producing electricity in January 1967, and reached half-load operation shortly thereafter. Its operation was subsequently interrupted, primarily due to the need to replace a calandria tube which had been damaged by an adjacent control rod and to repair damage sustained in varying degrees by all of the ten primary coolant pumps. The station went back into service in December 1967, and was operated at 85% availability during the peak-demand winter season. The station was brought to full power operation early in March, and with the exception of short outages as part of the commissioning programme, has continued to operate at this level.

3. As Douglas Point has assumed the power demonstration role formerly occupied by NPD, the latter reactor will now be used in a more experi-

mental capacity. To this end it was converted during recent months to operate with the heavy water coolant at boiling temperature, a mode of operation that is of particular interest in the Canadian nuclear power reactor development programme. Although the annual capacity factor is no longer a figure of merit, having regard to the experimental role now to be played by NPD, it is interesting to note that in the peak-load months during the past three winter seasons the station operated at capacity factors of 96.5, 97.9 and 99.96% respectively.

4. Ontario Hydro is making steady progress with the construction of the four 540-MW(e) units located at the Pickering nuclear power station. The four units will go into service during the period 1971/73 and will produce electricity at a lower unit energy cost than that produced by fossil fuel plants of comparable size in the Ontario Hydro system. It is noteworthy that fixed price tenders have been bid by Canadian industry for the fuel for the Pickering station which assure a maximum fuelling cost of 0.7 mills/kWh(e), which cost does not include any credit whatsoever for plutonium or spent fuel.

5. The construction of the 250-MW(e) Gentilly nuclear power station in the Province of Quebec, started in the fall of 1966, is progressing satisfactorily, and the original target date for having this station at full power by 1971 remains unchanged in spite of a lengthy construction strike. The reactor chosen for this station, CANDU BLW-250, is expected to demonstrate the practicability of using boiling light water as a coolant, the attainment of lower capital costs for heavy water reactors and a more efficient use of natural uranium. It is noteworthy that the walls of the reactor building — a structure 175 ft high and 120 ft in diameter, with walls 4 ft thick — were constructed in a period of only 18 calendar days through the use of the "slip-form" technique.

6. Construction of two 200-MW(e) CANDU stations at the Rajasthan Atomic Power Project in India is proceeding as schedules, as is the construction of the 137-MW(e) heavy water moderated, natural uranium fuelled, nuclear power plant at Karachi.

7. The demand for heavy water, both present and foreseen, is such that the expected production from the two heavy water production plants currently under construction in Canada will be inadequate. The construction of a third Canadian plant is currently being considered and it is expected that plans for its construction will be finalized by the year's end.

8. In July 1968 a contract was signed for the merger of the nuclear power plant engineering group of Canadian General Electric Company (CGE) with that of AECL. The objective of the merger, proposed by CGE, is to make the most effective and efficient use of Canadian nuclear design capability, both in meeting the demands of the domestic nuclear power programme and in competing for foreign orders. AECL has taken over the responsibility for the direction and support of the CGE systems group, which is now known as AECL Power Projects, Peterborough Division. The agreement is for a five-year period with appropriate termination arrangements.

9. The Commercial Products Group of AECL, responsible for the processing and marketing of radioisotopes and for the designing and marketing of associated equipment, has now installed more than 600 cancer teletherapy units in clinics and hospitals in 48 countries. Radioisotopes totalling more than 1.5 million curies were shipped during 1967-68, so that the cumulative total of isotope shipments by the Group now exceeds 8 million curies. A highlight of the year was the installation, in the Federal Republic of Germany, of Europe's largest medical products sterilization plant. It is loaded with 90 000 curies of cobalt-60 but has an ultimate capacity of 1.5 million curies. Another important development was the initiation of design work on a large-scale cobalt-60 sterilization unit for hospital use. The facility is to be built in the University Hospital at the University of Western Ontario. It will be used to study the effects of radiation sterilization of bulky articles such as hospital beds and medical machines, as well as surgical instruments, bedding and clothing.

10. Canada is also an important country as a source of nuclear fuel, and both the Government and the uranium industry are interested in promoting the export of uranium, subject to the conclusion of suitable agreements, providing for appropriate verification and control, to ensure that the uranium will be used for peaceful purposes only.

11. Production from the four operating uranium mines during 1967 was maintained at the 1966 level of approximately 4000 tons of U_3O_8. Meanwhile, mine development increased significantly in anticipation of additional demand over the next few years. Contracts providing for exports in excess of 17 000 tons of U_3O_8 were negotiated during the past year by the three major producers.

12. Exploration for Canadian uranium, essentially dormant since 1957, has increased significantly during the past year. The main centres of activity are focused around the three uranium producing areas of Elliot Lake, the Bancroft districts in Ontario and the Beaverlodge district in Saskatchewan. Although it is much too early in the programme to expect concrete results, reports to date have not indicated any new discoveries of significance. It is clearly evident, however, that foreign countries place con-

siderable faith in the potential for discovering additional deposits of Canadian uranium, as indicated by their increasing participation in and financing of exploration throughout the country. Canada welcomes this participation in the development of its uranium mining industry as a means of furthering international co-operation in the development of nuclear energy.

13. Developments have also been taking place in basic nuclear research in Canada. Ever since the early years of the century, when Rutherford's work in Montreal brought the first glimpse of understanding of nuclear rays, Canadian scientists have pursued the quest for knowledge in fundamental nuclear science. Particle accelerators are the most effective tool in research into the basic properties of the atomic nucleus, and the number of these devices has increased in Canada as its basic research programme has expanded. There are now 45 particle accelerators scattered across Canada in 23 different government, university and private research laboratories. Beam energies of 10 to 100 million electron volts can be achieved in 13 of these machines and energies in excess of 100 million electron volts in two machines.

14. Funds have recently been allocated to begin construction of the Can.$19 million tri-university meson facility to be known as TRIUMF, an H-minus cyclotron of unique capabilities which, in addition to its applications in nuclear physics, will provide Canadian scientists with an entry to the major field of intermediate energy physics. The beam characteristics, a maximum energy of 500 million electron volts and a maximum current of 100 micro-ampères will allow the production of large quantities of mesons for use as nuclear probes, and the study of the interaction of mesons with other elementary particles.

5. CEYLON

Progress in Peaceful Applications of Nuclear Energy in 1967/68

1. In 1959 the Agency sent experts to Ceylon to study the possibility of using atomic energy for peaceful purposes and, following their advice, the Radioisotope Centre was set up in the University of Ceylon to meet the needs of the University and outside institutions. The cost of building the Centre was borne by the Government, and the Agency provided most of the equivalent. Since 1961 the Centre, with the help of Agency experts, has been conducting under-graduate and post-graduate training courses and helping in the maintenance and repair of equipment.

2. A radiometric laboratory engaged in the study of radioactive minerals was also provided with experts' services and equipment by the Agency.

3. The Agency provided two experts to set up a radiological protection service, train local personnel, advise on the use of radiation in the treatment of cancer and establish a film-badge service.

4. Another Agency expert provided advice and training and set up a laboratory dealing with the use of radioisotopes in agriculture; a cobalt-60 gamma source was also provided for use in plant breeding. Ceylon is carrying out rice fertilizer studies and plant breeding and mutation studies with the help of the Agency, and it is hoped that an expert and equipment will be made available in 1969 to carry out genetic studies.

5. The Radioisotope Centre has assisted the Tea Research Institute in biochemical studies of the tea plant, using radioisotopes, and those studies are continuing. A number of Agency research contracts were awarded to the University of Ceylon, and an Agency expert also assisted in setting up a Radioisotope Clinic there.

6. The usefulness of the Agency's assistance was assessed in Ceylon by its Regional Officer for Asia and the Far East and his predecessor and by another Agency technical assistance expert, and the Government welcomed the proposal to appoint an Agency regional adviser on the industrial use of isotopes.

7. An Agency expert advised on the feasibility of using the sterile male technique to eradicate filaria and, following consultations with representatives of the Agency and WHO, it has been decided to draw up a research programme to be carried out during the next few years.

8. A Ceylonese expert on coconut and other plantation crops is working with the Agency, and radioactive material is being provided for experiments under his direction. The Agency has also provided training for two experts in its Laboratory, and it is being asked to assist in carrying out studies on fish preservation involving the use of radiation.

9. The Radioisotope Centre has trained teachers in the use of radioisotopes and is also in a position to offer such training to foreign students. Nationals of 11 countries participated in an IAEA Regional Course in Electronics held at the Centre in 1964, and it is hoped further courses of an international or regional character will be held there on such subjects as radiological protection and nuclear medicine. The conversion of the Centre into a regional centre for training and research would enable it to co-ordinate some of the Agency's projects in the region, permit foreign scientists to work there and promote the scientific and economic development of Ceylon. It is probable that the Agency will shortly install a neutron source in the Centre to irradiate material for subsequent radiochemical analysis. It is planned to carry out work on activation and isotope dilution analysis.

10. Having regard to the depletion of conventional power resources, the limited amount of hydroelectric power which will be available and the high cost of power, which hinders industrial progress, the time has come to study the need for nuclear power and to train the personnel required for its production and use. In that connection a research reactor might serve a useful purpose by enabling experts in different disciplines to work together.

11. It would be very helpful if the Agency could assist in the provision of spare parts for the equipment it has supplied, since such parts are often expensive and difficult to obtain. In selecting the equipment to be supplied, account should be taken of the types of equipment provided earlier so that spare parts could subsequently be interchanged.

12. The Agency should set up a regional centre to study the problems peculiar to each country in the area and ensure that work was carried out effectively. Such a centre might include a library to provide countries with urgently needed literature and co-ordinate the exchange of information on the results obtained, particularly with regard to regional projects.

13. The existing legislation has been modified to cover radioactive minerals, and a draft bill, covering the import, transport, storage and use of radioactive material and radioactive waste disposal, has been prepared. A Ministry of Scientific Research and a National Science Council have been set up by the Government with a view to facilitating the promotion of the peaceful uses of atomic energy and formulating the necessary regulations and codes of practice.

6. CHILE

Advances in the Peaceful Uses of Nuclear Energy

GENERAL ACTIVITIES

Nuclear policy and plans for development

1. The Chilean Nuclear Energy Commission commenced its activities in May 1966, and at the end of one year in office its Governing Board approved and submitted for consideration by the Chilean Government a report entitled "Nuclear policy and plans for development", which sets forth a line of action regarding all the principal aspects of the peaceful uses of nuclear energy.

2. These aspects are:

(a) Training, particularly in the basic sciences;

(b) Partial concentration of personnel, operations and equipment for training and research through the creation of a National Centre for Nuclear Studies;

(c) Prospection of Chilean soil for radioactive ores;

(d) Promotion of nuclear energy applications in agriculture and other spheres;

(e) Plans for the future development of nuclear power and possible applications in water desalination;

(f) Safeguarding the health of the population, with particular reference to persons handling radiation equipment and radioactive material.

Projects

3. In order to attain these objectives, the Commission has formulated the following principal projects:

(a) Establishment of a National Centre for Nuclear Studies, which is designed to

concentrate manpower and material resources available to the country in different branches of sciences and nuclear engineering, to co-ordinate basic and applied research, to provide academic training for university students and instruction in the handling and use of radioisotopes, and to make available the technical advice and services needed as a result of the growing interest in the use of radioisotopes and various irradiation techniques in medicine, agriculture, engineering, and so on;

(b) Establishment of a Radiological Protection and Control Centre. Act No. 16319 makes the Commission and the National Health Service responsible for the surveillance of users' installations and for the adoption of measures to protect the population from potentially hazardous ionizing radiations, for which purpose this programme has been drawn up;

(c) Prospection for radioactive ores. This project provides for resumption of prospection on the basis of agreements between the Commission and other organizations, such as the Geological Research Institute (Instituto de Investigaciones Geológicas) and the National Mining Organization (Empresa Nacional de Minería), for which the assistance of the Chilean Air Force and Army is also available.

4. The Commission's newly formulated programme, as summarized in the "Nuclear policy and plans for development" report, was submitted to the President of the Republic and to the Ministers and bodies concerned and was favourably received. At the express wish of the President, the period for completion of the programme, originally set at five years, was reduced to three years, starting from 1968. As a result, the Commission's efforts in 1967 were chiefly devoted to the preparation and implementation of these specific plans, though without neglecting the other activities incumbent upon it, which are also summarized in this report.

Technical assistance

5. Considerable technical assistance was rendered by the International Atomic Energy Agency (IAEA), as well as by other organizations, including the United States Atomic Energy Commission (USAEC) and the French Atomic Energy Commission (CEA).

6. An event of particular importance was the visit made by Dr. Dragoslav Popović, an IAEA planning expert. After six months' work in collaboration with the Commission, Dr. Popović submitted reports on the following topics:

(a) Uses of nuclear radiation;

(b) Exploitation of the cyclotron for making radioisotopes;

(c) Significance of the construction of a research reactor for the development of nuclear power;

(d) Prospection for radioactive ores;

(e) Nuclear power generation in Chile;

(f) Research reactors;

(g) Radioisotopes and nuclear radiation in Chile.

7. In addition, assistance was rendered by the following experts:

(a) Dr. Robson of the USAEC, expert in entomology;

(b) Mr. Peter Schwartz of the IAEA, expert in hydrology;

(c) Dr. D.A. Lindquist of the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, expert in entomology;

(d) Mr. K. Shea of the USAEC, expert in food irradiation;

(e) Mr. J-M. Huc and Mr. J. Hamard of the CEA, experts in the measurement of environmental radioactivity.

Agreement with France

8. *Purchase of a 5-MW nuclear reactor.* The Commission signed a basic agreement and various annexes with the CEA in April 1967. The principal purpose of this agreement is co-operation in the establishment of the National Centre for Nuclear Studies, the basis of whose activities is to be a research reactor. Among the main provisions of the agreement are those providing for an exchange of experts and the award of fellowships by the CEA. Later on, following negotiations in which the Minister for Foreign Affairs, Don Gabriel Valdés, made personal representations to the French Government and the Commission acted in an advisory capacity, a long-term credit was granted on favourable terms for the purchase of a 5-MW nuclear reactor.

Visit by the Chairman of the United States Atomic Energy Commission

9. *Gamma radiation unit for research purposes.* The Commission received a visit by Mr.G.T.Seaborg, Chairman of the USAEC, who was accompanied by a large group of representatives from the United States Department of State and the USAEC. A joint statement was issued in which the United States Representative announced the offer of an experimental gamma irradiation unit for food preservation research, as well as several fellowships for Chilean scientists and engineers.

Measurement of environmental radioactivity

10. The Commission drew up and published a complete report on measurements made during the previous year as a result of the French nuclear explosions. At the same time, the Commission specially appointed for these measurements continued its work throughout the year, using an improved system for the purpose. A technical specialist was sent to Easter Island to deliver replacements for the equipment already set up there. The French Government rendered assistance in this work through the services of Mr. Hamard and Mr. Huc[2].

Information services

11. The Commission took a number of steps to publicize work on the peaceful uses of nuclear energy, such as the issue of scientific information bulletins to the Press, the showing of films at the Chilean-French Cultural Institute, and the organization of a stand at the Industrial and Electrical Engineering Exhibition at the University of Chile.

12. A significant stimulus was given to the Commission's library, in the form of the acquisition, over the course of the year, of 2800 books on specialized subjects, the bulk of which were donated by international organizations. Over this period the library compiled a catalogue of authors, titles and subjects. It has circulated a detailed list of the various services available and published its first bibliographical bulletin, which provides both readers and other libraries with information on the collections available.

OTHER ACTIVITIES

13. *Regional course on nuclear power.* This course was given in Santiago under the sponsorship of the Agency.

14. Participation in the meeting of the Study Group on Research Reactor Utilization held at Bogotá, Colombia, and a visit to the Venezuelan reactor.

15. The following courses were attended by Chilean doctors and biologists:

(a) IAEA Regional Advanced Training Course on Medical Applications of Radioisotopes, Montevideo, November-December 1967;

(b) Symposium on Radiosterilization of Medical Products, Budapest, June 1967;

(c) Regional Training Course in Radiation Immunology, Buenos Aires, September-October 1967;

(d) International Training Course in Radiation Biology, Tel Aviv, May-June 1967.

16. *Medical and biological aspects of the application of irradiation techniques.* The Commission participated in the study of programmes on food preservation, sterilization of medical products, and irradiation of transplanted organs.

17. *Meeting on the use of nuclear energy to improve agricultural productivity.* This meeting, which was sponsored by the Inter-American Nuclear Energy Commission and the Organization of American States, was organized by the Chilean Commission. It was attended by 33 delegates from Argentina, Austria, Bolivia, Brazil, Colombia, Costa Rica, Mexico, Peru, and the United States of America, and also by 28 delegates from Chile. The topics dealt with were water research, plant research, soils and fertilizers, food irradiation and animal and insect studies.

18. *Agreement with the Institute of Plant and Animal Research (Instituto de Investigaciones Agropecuarias).* The Commission drew up a draft agreement, the chief aim of which is to supply the "La Platina" Experimental Station with the experimental laboratory equipment required to study the applications of nuclear energy in agriculture.

19. *Irradiation of food.* The Commission collaborated in studies on the feasibility of a food irradiation facility. To this end it held consultations with the Economic Co-operation Administration, requested the technical co-operation service of the Development Corporation (Corporación de Fomento) to make a study of the problem, and enlisted the support of the USAEC, as mentioned in the first part of this report.

20. The Latin American School of Physics (Escuela Latinoamericana de Física) held a session at Santiago in July 1967. This session, which was organized by the Commission, was attended by leading international specialists in solid-state physics, particle physics and nuclear physics.

21. The cyclotron was inaugurated in the middle of the year. The Commission played an important part in procuring financial aid for its construction.

2) See para.7(e) above.

7. COLOMBIA

Summary of Technical Operations carried out by the Institute of Nuclear Affairs August 1967 to July 1968

RADIOLOGICAL SAFETY

1. This is an operation of a permanent nature that continues to be carried out by a section of the same name. Studies have been made in the fields listed below.

2. Personnel dosimetry:

(a) Using film, to detect beta and gamma radiation, on a monthly basis;

(b) Using film, to detect neutrons, on a fortnightly basis;

(c) Using pocket monitors and direct-reading dosimeters, on a monthly basis.

This dosimetry covers the entire staff of the Institute of Nuclear Affairs (IAN) and occasional outside visitors, i.e. a total of roughly 80 persons. The results are recorded on appropriate personal record cards.

3. Calibration of sources and equipment. Using available equipment, ionization chambers, Geiger counters, dosimeters and scintillation counters were periodically calibrated with standards of attested activity. Other work carried out in this field includes personnel and area monitoring, decontamination, disposal of radioactive waste, checking on permits for the handling of sources, and listing and inspection of all IAN sources.

RADIOMETRIC STUDY OF ENVIRONMENT (ERA)

4. This programme involves continuous measurement of radioactivity in the environment (e.g., in samples of air, rain water, fresh water, vegetables, milk and fish). The findings are listed in monthly reports, a summary of which is published every six months and widely circulated.

5. During 1967 samples were taken at the following stations:

(a) Bogotá (IAN). Determination of total beta activity in samples of air, rain water, fresh water, milk, vegetables, and fish from the Pacific Ocean. Fission products were also determined in these samples, by means of gamma ray spectrometry.

(b) Medellín (ERA-1), Quidbó (ERA-2), Cali (ERA-3) and Leticia (ERA-4). These stations determined the total beta radioactivity and made a gamma spectrometer analysis of rain water and air samples.

6. This year new sampling stations have been set up at Pasto (ERA-5), Buenaventura (ERA-6), Bucaramanga (ERA-7). Furthermore, the programme has been further expanded to include the submission of biological samples by all stations, in addition to air and water. This monitoring system came into operation in June and will continue on an intensified scale. In addition, the stations are to begin determining the strontium and potassium content in the samples mentioned.

APPLICATION OF RADIOISOTOPES IN AGRICULTURE

7. Work accomplished in this field during 1967 can be summarized as follows:

(a) Maize. This programme was carried out under a research contract concluded between the IAEA and the IAN. Its purpose is to study the efficient use of fertilizers for this crop, particularly the interaction between nitrogen and phosphorus and its influence on crop yield. The experiments were carried out at the Nataima agricultural station near the town of Espinal. The nutrient sources used were superphosphate with and without ^{32}P-labelling, and ammonium nitrate and urea with and without ^{15}N-labelling;

(b) Rice. This programme was carried out at the Nataima experimental field and consisted in determining periods favourable for nitrogen application; ^{15}N-labelled ammonium sulphate was used for the purpose;

(c) Beans. This study was made in the IAN greenhouse and its purpose was to determine the proper time and dose for the application of phosphorus to beans via the leaves;

(d) Sorghum. Preliminary studies of the fertilization in this crop were made in a greenhouse. This year the sorghum fertilization experiment has been continued with the object of determining suitable doses for field studies.

8. Research has continued on phosphorus fixation in the rice-growing soils of the Cauca Valley. There have also been experiments on the effect of continuous application of phosphorus on phosphorus uptake in rice-growing soil.

9. In each case the results of these programmes have been summarized and will be published at a later stage.

IAN-R1 REACTOR

10. Operations of the IAN reactor are the responsibility of the Reactor Division. The reactor has been used without interruption by the unit since February 1965.

11. The activities of the Division during 1967 can be summarized as follows:

(a) *Operations:* 433 irradiations were carried out in the course of 305 irradiation periods, with an overall power consumption of 12708 kWh for the year;

(b) *Research:* Various parameters of the reactor, such as its reactivity coefficient with temperature and its sensitivity to neutron absorbers were determined. The calculation of epithermal and fast neutron fluxes was begun;

(c) *Publications:* A variety of investigations were carried out and published as a paper under the title "Determination of various parameters of the IAN-R1 reactor". This paper was presented at the Third Colombian Congress on Physics and at the Study Group Meeting on Research Reactor Utilization held on December 11-15, 1967 in Bogotá;

(d) *Other activities:* Preventive maintenance of the reactor and training of operational personnel. A reactor physics course was given for final-year students of the Department of Physics at the National University. Students were given advice on degree theses dealing with various aspects of the reactor.

12. In the first half of 1968 the IAN continued to make its irradiation service available for different technical operations; gold seeds for medical purposes were irradiated and used at the Cancerology Institute. There has also been progress in work on calculation of the mean temperature of thermal neutrons. Various experiments relating to the design of neutron detectors based on beta-emitting radionuclides have been carried out with good results.

RADIOCHEMISTRY

13. The Radiochemistry Section carried out research in the following fields:

(a) *Activation analysis:*

(i) Determination of selenium and tellurium in natural sulphur;

(ii) Study of sensitivity in determining halogens with the IAN-R1 reactor;

(iii) Calculation of potassium, chlorine and magnesium in wheat, maize and barley seeds;

(iv) Calculation of iodine in urine specimens;

(v) Calculation of uranium and thorium in the ores containing them, by the delayed neutron counting technique, using boron trifluoride detectors. The results of this research were presented at the Bogotá meeting on research reactor utilization.

(b) *Radioisotope production:*

(i) Production of carrier-free ^{32}P;

(ii) Production of ^{32}P-labelled calcium superphosphate from commercial superphosphate, using the mechanism of exchange between the ^{32}P solution and the commercial fertilizer;

(iii) Production of ^{32}P-labelled potassium metaphosphate with properties similar to the commercial product. In the greenhouse experiments conducted by the Agricultural Section use was made of fertilizers labelled in the IAN-R1 reactor;

(c) *Research in nuclear chemistry:*

(i) Isolation of nuclear isomers (mercury-197m and mercury-197), by means of diethyl mercury and mercury dithizonate;

(ii) Development of new radioisotope generators utilizing recoil energy from a daughter nuclide when the parent nuclide is contained within a complex. The synthesis of various phthalocyanine complexes from phthalodinitrile by means of a variety of catalysts was studied. Fourteen different complexes were synthesized so as to study the possibilities of fixation in exchange resin or aluminium oxide columns;

(d) *Radiation chemistry:*

(i) Work was continued on improving the physical properties of wood (Cuangaré). The technique is based on impregnation of the wood with a monomer (methyl methacrylate) and inducing of polymerization by means of radiation, the IAN-R1 reactor being used for the purpose;

(ii) This year saw the continuation of activation analysis to determine the vanadium in crude oil and in the different fractions during refinement. Activation analysis of iodine in blood was also made and the search for new generators continued, more specifically, those of the palladium-rhodium type;

(iii) ^{32}P-labelled fertilizers were supplied, as before, for greenhouse experiments and laboratory tests made by the Agricultural Section.

APPLICATION OF RADIOISOTOPES IN INDUSTRY

14. During 1967 the main effort was oriented towards industrial scintigraphy. ^{60}Co and ^{192}Ir sources were used for making a series of inspections of weld seams in pressure tubes at the Rio Mayo Hydroelectric Station, and scintigraphs of two compressors were made for a soda plant in Cartagena.

15. Work was started on the fitting out of a laboratory which will provide an information service on the practical use of radioisotopes in industry.

16. The scintigraphy service continued to operate in the first half of this year.

17. Investigations were carried out to localize blockages in the oil pipeline owned by the Empresa Colombiana de Petróleos, for which use was made of a ^{60}Co source of approximately 240 mCi secured to the back of the scraper. The section inspected covered approximately 200 km.

PROSPECTION FOR RADIOACTIVE MINERALS

18. During the year 1967 prospection work was carried out by groups made up of IAN geologists:

(a) Group I in the Department of Santander (Bucaramanga, Pajuil, Matanza, Charta, Suratá, Cachirí, Vetas, California, Jordán, Mesa de los Santos, and the Bucaramanga-Puerto Wilches Railway);

(b) Group II, north of Santander (Bochalema, Chinácota);

(c) Group III, north of Santander (Pamplona-Cácota-Mutiscua);

(d) Group IV, in Boyacá (Duitama, Surba River Valley).

The findings of these groups are published in the relevant reports. Generally speaking it can be stated that in the areas studied there were found deposits of lignitic coals, shales and uranium-bearing phosphates.

19. The following work has been carried out this year:

(a) Group I, north of Santander (Durania - La Don Juana);

(b) Group II, north of Santander (Arboledas);

(c) Group III, north of Santander (Chitagá);

(d) Group IV, north of Santander (west of Arboledas).

The results confirm the presence of uranium-bearing pegmatites detected in 1967.

ENTOMOLOGY

20. A programme has been worked out for co-operation between the Colombian Plant and Animal Institute (Instituto Colombiano Agropecuario) and the IAN in the study of ways of controlling *Heliothis* spp., *Diatraea* spp., and *Dermatobia* spp. by means of gamma radiation, and the findings will be reported to the United Nations.

21. The IAN has also assisted in the formulation of a nation-wide programme for integrated control of cotton pests, which will be submitted to the United Nations Food and Agriculture Organization together with a request for economic and technical assistance. Among other measures, preliminary arrangements have been made for the installation of facilities required to study the breeding of *Diatraea* spp. under laboratory conditions and the creation of artificial diets for this insect.

8. CONGO, DEMOCRATIC REPUBLIC OF THE

The Peaceful Uses of Atomic Energy

CONVERSION OF THE TRIGA MARK I REACTOR

1. The Commissariat des Sciences Nucléaires is carrying out major alterations in the Triga Mark I reactor at the Centre Nucléaire TRICO with a view to meeting fully the requirements of a regional centre for training and the use of radioisotopes. The aim is to convert the reactor into a new type of reactor, the Triga Mark II model, with an output of 250 kW, and to construct a new complex of buildings around it containing radiochemistry, radiobiology, radioagronomy, and nuclear physics laboratories together with the offices of the Commissariat des Sciences Nucléaires and the documentation service of the TRICO Centre. The components required for the new reactor are already on the spot or in course of delivery and it was planned to start the construction of the new building in September 1968.

RESEARCH

2. The following research work was carried out at the TRICO Centre:

(a) Activation analysis in soil science
- Determination of the quantity of aluminium and silicon in Congolese soil;
- Determination of the quantity of manganese cobalt and magnesium in zeolites;

(b) Medical research (whole-body counter)
- Intestinal absorption of iron;

(c) Theoretical research
- Development of four programmes in FORTRAN[3] for research workers in the chemistry-physics group;
- Calculation of the Steinheimer anti-screen factor;

(d) Electronics research
- Development of a noise generator using a radioactive source.

Activation analysis in soil science

3. *Determination of the quantity of aluminium and silicon in the soil.* The research workers have carried out analyses with a view to determining the quantity of aluminium and silicon in the soil. The irradiation work was completed on 15 June 1968; over 600 samples were irradiated.

4. *Determination of the quantity of manganese, cobalt and magnesium in zeolites.* The determination of the quantity of manganese, cobalt and magnesium in zeolites was completed. During the latter part of the work, manganese was measured by integral counting. The results are satisfactory. An account of the work can be found in the TRICO Centre's research report no.15 (1968).

Medical research

5. The TRICO Centre has continued its research on intestinal absorption of iron. Twenty subjects were treated and a further ten are being prepared. Plans were made to complete the first part of the work on 15 July 1968; this work consisted of 160 (20 × 8) measurements of subjects and ±100 measurements of calibrations. The second part of the work, namely the study of caesium-137 and potassium-40 in the population, will be carried out when all the equipment required is available.

Theoretical research

6. Four programmes in FORTRAN have been developed for the computer in Lovanium University

3) Formula Translation Computer Programming Language.

which will permit the chemists in the chemistry-physics group to interpret the results of their measurements by deducing the order and constant of velocity in the kinetic reactions. These programmes can be found in the TRICO Centre's operational report no.15 (1968).

7. The calculation of the Steinheimer anti-screen factor is continuing. Programmes for machines for angular transition calculations have been developed and the results obtained are correct.

Electronics research

8. A noise generator using a cobalt-60 radioactive source has been produced in the electronics department with characteristics which are superior to those of the same type in commercial use.

SYMPOSIUM ON THE PEACEFUL USE OF ATOMIC ENERGY AND THE DISTRIBUTION OF ELECTRICAL ENERGY IN AFRICA

9. Under the auspices of the Organization of African Unity, the Commissariat des Sciences Nucléaires proposes to hold a symposium on the peaceful use of atomic energy and the distribution of electrical energy in Africa at Kinshasa in April 1969[4]. It is hoped that the International Atomic Energy Agency will co-operate in organizing this symposium, which would be of interest to States in the region.

TRAINING OF STAFF

10. Particular importance is attached to the training of African scientific staff. A Congolese reactor operator has been trained. A number of science students will be taken on during their holiday periods so that they can be initiated into nuclear research work.

9. CYPRUS

In reply to the Director General's invitation to communicate a statement, the Government of Cyprus has informed him "that except for the installation of a cobalt teletherapy unit, which has been operating since January 1966, no further progress has been made in Cyprus in the peaceful application of nuclear energy."

10. GERMANY, FEDERAL REPUBLIC OF

Progress Report on the Applications of Nuclear Energy in 1967/68

THIRD GERMAN ATOMIC ENERGY PROGRAMME

1. The period covered by the Second German Atomic Energy Programme (1963 to 1967) ended in 1967. After detailed discussions the responsible government authorities, German scientists and industry jointly worked out the follow-up programme covering the years 1968 to 1972. On 13 December 1967 the Federal Cabinet approved the Third German Atomic Energy Programme. Thus, for the first time and in contrast to its predecessors, this is a government programme. It is attuned to the Government's medium-term financial planning and provides funds totalling DM 5000 million. About 50% of these funds are to be allocated for nuclear research and about 50% for nuclear development.

2. In the Third German Atomic Energy Programme the main emphasis is placed on high-energy physics and nuclear solid-state research in the field of fundamental research, on gas-cooled high-temperature reactors and fast breeder reactors in the field of nuclear engineering and on mastering of the technology of the fuel cycle. The work of the large nuclear research centres and international co-operation are of special importance for the realization of the programme.

FURTHER INCREASE IN THE FEDERAL REPUBLIC'S FUNDS FOR THE ADVANCEMENT OF THE NUCLEAR ENERGY SECTOR IN 1968

3. In 1968 the Federal Government will allocate approximately DM 860 million for the advancement

4) The provisional programme of the symposium is available for consultation in the Agency's Library.

of nuclear research and development; this means an increase of 11% as compared to the previous year. These funds will be spent as follows:

(a) 32% on nuclear development, including the construction and operation of large experimental nuclear facilities, outside the nuclear research centres;

(b) 28% on the nuclear research centres;

(c) 28% on international co-operation;

(d) 10% on nuclear research at the universities and at institutes outside the universities; and

(e) 2% on radiation protection and reactor safety.

4. Of the DM 860 million, DM 660 million i.e. more than three quarters of the Federal Funds, will come from the budget of the Federal Ministry for Scientific Research. In addition to the Federal Funds, another DM 200 million will be made available by the Laender. Thus in 1968 government funds amounting to approximately DM 1060 million will be allocated for the advancement of nuclear research and development.

INCREASED EXPERIENCE AND ACHIEVEMENTS OF THE REACTOR INDUSTRY IN THE FEDERAL REPUBLIC

5. On 1 July 1968 nuclear power stations with a net electrical output of altogether 2200 MW(e) were in operation or under construction in the Federal Republic. In 1967 electric power generation from nuclear energy reached a total of 1200 million kWh, which was five times as much as the amount generated in 1966.

6. At the beginning of 1968 the Argentine National Nuclear Energy Commission placed an order with a German firm for the construction of a nuclear power station with a natural uranium pressurized heavy-water reactor with an output of 320 MW(e). The site chosen for the station is Atucha, approximately 100 km north-west of Buenos Aires. This is the first export order for a nuclear power station constructed in the Federal Republic. The plant will be the first nuclear power station in South America.

7. At Würgassen and Stade in North-West Germany, construction work has started on the two large commercial light-water nuclear power stations, the building of which was decided on in 1967.

8. Of the three nuclear power demonstration plants of the light-water type at Gundremmingen, Lingen and Obrigheim respectively, the reactor at Gundremmingen, on the Donau, has been in operation since 1967. The second plant at Lingen, on the Ems, went critical early in 1968 and reached its full electric power output on 13 July. The third demonstration plant at Obrigheim, on the Neckar, is to reach criticality for the first time before the end of this year.

9. Since the construction orders for the two large nuclear power stations in North-West Germany were issued, the preparations of the German utility companies for ordering additional plants have made good progress. In mid-1968 the largest German power supply company announced that within the foreseeable future it intended to start on the construction of a light-water nuclear power station, with a power output of more than 1000 MW(e), to be situated in South-West Germany. In addition to generating electricity, the plant is to produce process steam for the chemical industry. A similar project to be located in the Ruhr district is under discussion.

10. Progress has also been made in the field of gas-cooled high-temperature reactors; the AVR reactor at Jülich, near Cologne, has gone into full operation. It has spherical fuel elements and has a power output of 15 MW(e).

11. The development and designing of the THTR thorium high-temperature reactor of the pebble-bed type, with an electrical output of 300 MW(e), conducted co-operatively by the European Atomic Energy Community (EURATOM), a German industrial firm and the Jülich nuclear research establishment, was completed with the presentation of the designers' plans as approved. It is expected that, with the Government's support, German utility companies will decide within a few months to build this prototype plant.

12. Early in 1968 a decision was taken to construct a 25 MW(e) experimental nuclear power station with a high-temperature reactor containing prismatic fuel elements, and a helium turbine in a direct cycle. The plant is to be located near Geesthacht in Schleswig-Holstein. The final objective of German high-temperature reactor development is the construction of commercial nuclear power stations with helium turbines.

13. In the field of fast breeder reactors, the Karlsruhe nuclear research centre and German industrial firms continue their joint research and development work on a 300 MW(e) prototype plant.

14. The building for the KNK compact sodium-cooled nuclear power station at Karlsruhe, which is to serve as a test bed for breeder reactor elements and for testing sodium technology, has been completed, and assembly of the reactor plant is progressing. The plant is scheduled to go into

operation in 1969. The construction of the HDR superheated-steam reactor at Grosswelzheim on the Main is nearing completion, so that this plant too can go into operation next year.

15. At the end of 1967 the nuclear ship "Otto Hahn" went on her first trial cruise using a conventional auxiliary propulsion system. On land, the reactor, which is to be built into this bulk carrier, reached criticality for the first time. At present the reactor is being installed. The first "nuclear cruise" of the "Otto Hahn" is scheduled for the end of 1968.

16. In early 1968 the Federal Ministry for Scientific Research placed an order with German industrial firms for the development and design of an in-core thermionic reactor with an approximate output of 50 kW(e). The reactor is intended to supply electric power for satellites.

ADDITIONAL ACTIVITIES CONNECTED WITH THE SUPPLY OF NATURAL URANIUM AND WITH MASTERING THE TECHNOLOGY OF THE FUEL CYCLE

17. During the period under report, firms of the metal and mining industry founded the Urangesellschaft mbH & Co. KG at Frankfurt on the Main and the Uranerzbergbaugesellschaft at Bentheim. The two companies will engage in the prospection, mining and refining of uranium ores. Business connections with foreign countries have been established.

18. The building for the first German reprocessing plant for irradiated nuclear fuel elements at Karlsruhe has been completed and its equipment is at present being installed. The plant is scheduled for operation in 1969.

19. In co-operation with the Karlsruhe nuclear research centre, German industry has taken up development work for an industrial plant which is to manufacture fuel elements containing plutonium, especially for fast breeder reactors.

20. In the Asse salt mine near Wolfenbüttel in North-West Germany another batch of low-activity radioactive wastes has been given trial storage by the Gesellschaft für Strahlenforschung mbH.

FURTHER INSTALLATIONS FOR NUCLEAR RESEARCH

21. For the extension of the German electron synchrotron DESY at Hamburg, having a maximum energy output of 6.5 GeV, the installation of a new injection linear accelerator was begun. To supplement this installation, electron-positron storage rings (3 GeV) are being planned.

22. At the Jülich nuclear research centre an isochron cyclotron for the acceleration of deuterons with variable energies (45 and 90 MeV) was put into service. Another accelerator of the same type but with lower energy is at present being erected at Bonn University.

23. For the preparation of research work using heavy ions in the fields of low-energy nuclear physics and of nuclear chemistry, a working group at Heidelberg University is continuing the development of a heavy-ion accelerator.

24. On 30 June 1968, 17 research reactors and 10 small training reactors were in operation in the Federal Republic. As for the larger research reactors, it was possible to increase the power output of the DIDO research reactor in the Jülich nuclear research establishment by 50% to 15 MW(th), and that of the FRG 1 reactor at Geesthacht near Hamburg from 5 to 15 MW(th).

25. The measuring reactor of the Physikalisch-Technische Bundesanstalt at Braunschweig reached criticality for the first time in the second half of 1967. Two impulse reactors have been ordered for medical and radiobiological research activities.

USE OF LARGE-SCALE RADIATION SOURCES

26. In order to carry out radiochemical research activities, the Technical University at Munich has been equipped with a ^{60}Co large-scale radiation source with an activity of 10 kilocuries (kCi).

27. As an experiment an industrial firm has started to use a new ^{60}Co large-scale radiation source, with an activity of 90 kCi, for the sterilization of medical instruments.

INTERNATIONAL CO-OPERATION

28. The close scientific and technological co-operation within EURATOM has been continued. The intensive co-operation in the field of high-energy physics within the European Organization for Nuclear Research (CERN) has also been pursued.

29. Following the agreements for co-operation in the development of sodium-cooled fast breeder reactors concluded between the Governments of the Federal Republic, Belgium and the Netherlands, a contract for collaboration in the construction of a 300 MW(e) prototype nuclear power station has now been signed by the participating industrial companies of the three countries. The power utility companies of the three countries have started discussions concerning the selection of a site.

30. Preliminary planning for the bilateral German-French Max von Laue — Paul Langevin-Institute at Grenoble, which is to be equipped with a very-high-flux reactor for research work, has been concluded. The preliminary project comprises all the results obtained so far with respect to planning and development for the construction of the reactor. It will serve as a working document for the invitations to tender which will now be issued to German and French industrial firms.

11. GREECE

Progress Report on Applications of Nuclear Energy in 1967/68

DEVELOPMENT AND UTILIZATION OF ATOMIC ENERGY

1. On 19 June 1968, Law No.451 was passed to provide for the reorganization of the Greek Atomic Energy Commission (GAEC). All previous Laws and Legislative Decrees are now invalid. According to the new Law, the fostering, supervision and control of all kinds of applications of atomic energy in Greece are under the authority of GAEC.

2. As mentioned at the 11th regular session of the General Conference, Greece is not only interested in fundamental research but also in the application of nuclear energy,[5] and in this light GAEC has taken the appropriate measures to encourage the introduction of nuclear power in this country. GAEC will provide the necessary training for some of the engineering staff of the Public Power Corporation, at its request, in reactor engineering work, in anticipation of the possible construction and operation of its first nuclear power plant.

3. In the field of hydrology GAEC has been in contact with the Land and Reclamation Service of the Ministry of Agriculture and the Institute of Geology and Subsurface Research for the hydrological investigation of various parts of the country, after a proposal by the Agency to provide experts and certain laboratory facilities to assist in this project.

DEMOCRITUS NUCLEAR RESEARCH CENTRE

4. At the Democritus Nuclear Research Centre (DNRC) the production of radioisotopes and labelled compounds for medical, scientific and industrial applications continues to expand. The radioisotopes are distributed to various medical centres for clinical and diagnostic use, to industry for radiography and to the various laboratories for fundamental and applied research purposes. The reorganization of the Radioisotope Production Group, with the assistance of an Agency expert, is expected to increase the supply of radioisotopes. Greek industry is continually expanding the use of radioisotopes for various applications, and GAEC advises interested parties on the possibilities existing in this field.

5. A radiation damage project is being carried out in collaboration with the Garching Nuclear Research Centre at Munich. The programme in the field of nuclear chemistry and activation analysis, hot-atom chemistry in solids and liquids, radiation chemistry and physical chemistry are being successfully continued.

6. The Biological Sciences Group is contributing to protein chemistry, enzymology, photosynthesis, the study of lipids, physiology and genetics in fungi, marine biology and the control of the *Dacus oleae* fly.

7. The Soil Science and Plant Nutrition Groups are actively investigating problems of genetic classification, fertility and nutrition.

8. In the field of geology an investigation was carried out with the assistance of an Agency expert, the results of which were favourable, and continuation of the project on the evaluation of radioactive ores is under contemplation.

9. The Health Physics Group is continuing the programme of radiological surveys, environmental monitoring, waste disposal and dosimetry.

10. Reactor physics, delayed neutron research and reactor dosimetry are being developed in the Reactor Technology Division.

11. The High-Energy Physics Group is making good progress in on-line application of computer systems and in pattern generation and recognition. A Hough and Powell device to carry out programmes in high-energy physics in collaboration with the European Organization for Nuclear Research (CERN) is now nearing completion.

5) See document GC(XI)/OR.115, para.80.

12. DNRC plans to increase the power of the reactor and to install a linear accelerator; this will assist the physicists to extend their research projects. The linear accelerator will especially assist expansion of solid-state research into radiation damage, studies of nuclear reactions and their cross-sections, and the examination of short lifetime, fission and stripping and pickup reactions. It will also make possible an expansion of programmes in radiation chemistry, especially by pulsed radiolysis, to study intermediate short-lived products, and nuclear chemistry in the fields of short-lived radioisotopes, transuranic elements and hot-atom chemistry. The Biological Sciences Group will use the accelerator in basic and applied research, such as studies of the genetic effects of radiation and food preservation.

13. A programme to facilitate and broaden the distribution of scientific and technical information comprises the publication of reports. These reports are placed in the Library of DNRC and some 6000 volumes and 35 000 reports are available for all persons interested in the field of nuclear energy.

14. The inauguration of DNRC's School of Nuclear Science and Technology took place on 8 January 1968. Approximately 30 post-graduates, physicists, medical doctors, etc. have attended the school to further their studies of peaceful applications of nuclear energy.

SYMPOSIA AND MEETINGS

15. The first National Hellenic Congress of Oncology took place in Athens from 10 to 13 April 1968. This conference was organized under the joint auspices of the Hellenic Anti-Cancer Institute and GAEC. Some 200 scientists from all over the world attended.

16. An Agency study group meeting on health physics was held in Athens from 16 to 20 October 1967. Approximately 40 participants from Middle East countries and several representatives of world organizations attended the meeting.

TECHNICAL ASSISTANCE

17. A number of Agency fellowships were awarded to applicants from DNRC and other research institutes. Two scientific visits were arranged under the Agency's technical assistance programme to enable scientists to visit laboratories abroad which were specialized in the application of radioisotopes in industry and hydrology.

18. Numerous Greek scientists attended conferences, study group meetings and symposia and participated in study tours during the period covered by this report.

19. The valuable assistance of Agency experts enabled DNRC to evaluate its present and future programme.

AGENCY RESEARCH CONTRACTS

20. Renewals of Agency research contracts were awarded to DNRC to continue research on delayed neutron spectrum measurements and also to the Alexandra Hospital for the continuation of radioisotope studies on endemic anaemia.

21. Two new contracts were awarded, one to the Biology Division of DNRC in support of the project on the use of radiation and radioisotopes in a study of the physiology of fungi toxicity and of the development of fungicide resistance in pathogenic fungi, and the other to the University of Athens for a project concerning the effect of gamma-irradiation on the lipid metabolism of radiosensitive tissues.

INTERNATIONAL CO-OPERATION

22. During the period under review the laboratories of CERN at Geneva were used by several scientists for further studies and co-operation on high-energy physics and computing methods.

23. Under a bilateral agreement the United Kingdom Atomic Energy Authority will transfer a sub-critical nuclear assembly to the National Technical University of Athens to assist the staff and students to do practical work as part of their courses in nuclear physics and engineering.

12. INDIA

Progress made by India in the Peaceful Uses of Atomic Energy during 1967/68

1. India continued to make steady progress in the peaceful applications of atomic energy during the year 1967-68. A brief review of the developments is given below.

2. Work on the construction of the 380-MW(e) Tarapur Atomic Power Station continued and, in spite of certain unexpected difficulties, it is expected that the station will be in commercial operation by March-April, 1969. The construction of the two 200-MW(e) units in the Rajasthan Atomic Power Station is progressing as scheduled. Work on the first 200-MW(e) unit of the Madras Atomic Power Station has commenced. With the commissioning of these three stations, India will generate about 1000 MW(e) of nuclear power in the early seventies. A new unit designated as the Power Project Engineering Division has been created by the Atomic Energy Commission with responsibility for the design, construction and commissioning of the Madras Atomic Power Station. This unit is also responsible for the construction and commissioning of the Rajasthan Atomic Power Station. Plans are under active consideration for the setting up of additional nuclear power stations to provide a total of about 3000 MW(e) by 1980.

3. Simultaneously with these developments, a working group was constituted to study the technological and economic implications of agro-industrial complexes around large low-cost nuclear energy centres. Such studies are of particular interest to India in relation to the potentialities of an agro-industrial complex in regions such as the Indo-Gangetic plain and Kutch-Saurashtra.

4. The Plutonium Plant operated continuously during the year. Plans are well under way to establish a reprocessing plant at Tarapur for treating irradiated fuels from the Tarapur and Rajasthan power reactors. The design of a pilot plant for treating thorium and thorium-oxide irradiated in the CIRUS reactors at Trombay, for the recovery of uranium-233, has been completed. The pilot plant is expected to be commissioned in the next few months.

5. To meet the fuel requirements of India's power reactor programme, a nuclear fuel complex consisting of a uranium-oxide plant, a zirconium plant and a ceramic fuel fabrication plant is being set up at Hyderabad. This complex will also have a special materials plant where high-purity materials required for India's electronics industry will be produced. Steps have further been initiated for the construction of a heavy-water plant near the Rajasthan Atomic Power Station. This plant will have an annual capacity of 100 tons of heavy water. Work on the uranium mine and the uranium mill at Jaduguda continued to register steady progress. The mine shaft is expected to be commissioned shortly and the mill is going through trial runs. Parallel with these developments, feasibility studies have been initiated on a fast test breeder reactor.

6. The large electronics complex set up at Hyderabad commenced production of a wide variety of nuclear instruments, control systems, computers and electronic components to cater for the increasing, countrywide demand for such types of equipment.

7. For the effective co-ordination and implementation of the above projects, a number of undertakings have been set up by the Government. One is the Uranium Corporation of India Limited, which is responsible for the development of the uranium mine and the operation of the uranium mill at Jaduguda. Another is the Electronics Corporation of India Limited, which is responsible for the operation of the electronics complex at Hyderabad. Another company set up by the Government much earlier, the Indian Rare Earths Limited, is at present engaged in an expansion programme for the increased production of ilmenite, monazite, rutile, zircon etc.

8. The Atomic Minerals Division of the Atomic Energy Commission continued its countrywide prospecting for uranium, thorium, beryllium and other minerals of interest to the atomic energy industry. This Division is currently engaged in a programme of introducing modern methods of survey and investigation and in strengthening the laboratory and other facilities essential for such a programme.

9. At the Bhabha Atomic Research Centre at Trombay, research and development work continued as in earlier years. A number of items of equipment such as radiography cameras, gamma chambers, nuclear data processing equipment, glass-working lathes and molecular centrifugal stills were developed. A process has been developed for the production

of uranium oxide powder, sintering to a high density of the order of 10.8 g per cc. This oxide will be of great value in the production of ceramic fuel for reactors.

10. Two new laboratories were set up at the Bhabha Atomic Research Centre during the year under review. One is the Electronics Prototype Engineering Laboratory, which undertakes production engineering relating to the various types of electronic and allied equipment designed and developed in various laboratories of the Centre. The other is the Reliability Evaluation Laboratory, which tests, measures and evaluates the reliability of electronic components, instruments and systems. Facilities for the production of radioisotopes and labelled compounds were expanded and diversified and radioisotopes were exported to a number of countries.

11. Work was successfully continued in the plant mutation breeding programme. A number of new radiation-induced mutants with improved agronomic characteristics were obtained. The food irradiation and processing laboratory was substantially completed and two cobalt-60 irradiators, one of 27 800 curies for free-flowing materials such as grain flour and spices and the other of 100 000 curies for pre-packaged foods, were installed.

12. The Seismic Array at Gouribidanur, which has been set up for the study of underground nuclear explosions, was brought up to its full complement of 20 seismographs extending over an area of 25 km × 25 km. The analysis of fall-out debris from nuclear explosions was continued.

13. At the Tata Institute of Fundamental Research, an on-line data processor has been designed and built. It has now been installed as a computational facility for the processing of experimental results. Large plastic balloons of volumes as high as 85 000 m^3 are now being routinely made at the Institute for high-altitude cosmic ray studies. All the electronics units necessary for the large cylindrical radio telescope to be set up at Ootacamund have been designed and built. The development of microelectronic integrated circuits and micro-wave test equipment is now in progress.

14. Experimental investigations on cancer were continued at the Tata Memorial Centre. A project is now in progress in which chemotherapy and radiotherapy are employed together in treating certain forms of cancer.

15. Steps have been initiated to make and install a variable energy cyclotron near Calcutta. This cyclotron will serve as a national facility for research in nuclear physics and for controlled, direct irradiation of biological and agricultural products. Because of its high beam intensity, the cyclotron can produce a variety of isotopes which cannot be produced in nuclear reactors. This facility will be of great help to workers in Indian universities and in research establishments.

16. The Department of Atomic Energy continued to provide financial and other forms of assistance to a number of universities and institutions in India, which are engaged in research and development work in the field of atomic energy.

13. IRAQ

Atomic Energy in Iraq

INTRODUCTION

1. Following the First International Conference on the Peaceful Uses of Atomic Energy, held in Geneva in 1955, it became clear to the policy makers that a developing country such as Iraq could benefit greatly in the course of its economic and cultural progress by sponsoring a programme in both fundamental and applied nuclear research. This conclusion was also based on the fact that the establishment of a nuclear research centre, together with a sound programme of work, is a correct step in an effort to reduce the widening technological gap between developing countries and the more advanced industrial countries.

2. Specific practical problems relating to industry and agriculture in Iraq could most easily be solved by utilizing well-established radioisotope and irradiation techniques. Those problems are closely linked with, and largely dependent upon, local and environmental conditions and one could hardly expect them to be tackled by experimentalists working elsewhere.

3. It is recognized that the short-term benefits to Iraq's economy could be immediately derived through an early solution of the more important of these specific practical problems and it might be argued that the financial support allocated for more fundamental research is excessive at best. However, this argument is invalidated by the fact that a dynamic

contact should always be maintained between those engaged in applied and fundamental research and that such contact is essential for the exchange of new ideas and techniques, from which the former will benefit greatly. In addition, Iraq is considered to be scientifically isolated and somewhat remote from technological centres. It is therefore essential that fundamental research should be encouraged from within rather than be dependent solely on external achievements.

4. The establishment of a nuclear power programme may be considered to be uneconomic in Iraq at present, but the skeleton scientific and technical manpower required to operate and maintain any future installations will be available, if it is needed in future on economic grounds.

5. It is a recognized fact that the developing countries are losing some of their best trained scientists and technologists to the industrial Powers. This is mainly due to the lack of proper research facilities and a suitable environment for work. From the scientific point of view such a state of affairs is close to a national catastrophe, which is bound to have adverse long-term effects on any country's future. By building up its research facilities and activities, Iraq intends to encourage more of its scientists to work in their homeland. In this way, its scientific efforts will be enhanced and its manpower increased so that the country at large can look forward to a future existence, in the midst of a highly technological world, with more confidence.

6. The foregoing are some of the more important considerations which gave birth to the Iraqi Atomic Energy Commission (IAEC).

SOME HISTORICAL NOTES ON THE DEVELOPMENT OF IAEC

7. On the recommendations of a ministerial committee that was set up in 1955, IAEC was established in 1956 under the chairmanship of the Minister of Development. It was charged with formulating its charter, defining the programme for its future work, supervising the progress of this work and generally looking after matters related to its sphere of interest. Its first charter appeared in the official gazette in January 1959; since then a number of changes have taken place and its responsibilities have expanded. Today, IAEC is a semi-official organization attached directly to the Council of Ministers and has the Prime Minister as its Chairman. The Vice-Chairman of IAEC is the Chairman of the Science Research Council. Other members of IAEC are appointed from among those in various Departments of State who are actively interested in atomic energy.

8. IAEC plays the role of an advisory council in establishing and guiding Government policies in the field of atomic energy and allied problems. Other, more specialized committees on scientific and safety aspects have also been set up.

9. Operating under the auspices of IAEC are the Nuclear Research Centre and the cobalt-unit hospital. IAEC is planning to establish two more cobalt-unit hospitals, the first in Mosul and the second in Basra.

INTERNATIONAL CO-OPERATION

10. Iraq is a member of the International Atomic Energy Agency (IAEA). It is currently receiving technical and financial assistance from the IAEA under its regular programme and also under the United Nations Development Programme.

11. In 1959 the Republic of Iraq signed an agreement with the Union of Soviet Socialist Republics for co-operation in the peaceful uses of atomic energy. As a result of this agreement, Iraq purchased its reactor and radioisotope laboratory hardware from the Soviet exporting firm "Technopromexport".

12. Fully realizing the true international nature of science, Iraq is pursuing an active policy with a view to widening its international co-operation activities with interested countries.

THE NUCLEAR RESEARCH CENTRE

13. This is the main centre in Iraq for nuclear research. It is situated about 20 km south of Baghdad off a main trunk road. It now has a staff of 250, of whom 100 are university graduates. The centre is administratively linked with IAEC through the offices of the Secretary-General in the city of Baghdad. The Divisions comprising the Centre at present and the general sphere of interest of each Division and its future plans are listed below.

Reactor Operations Division

14. This Division is responsible for the nuclear reactor systems and the operation, modification and maintenance of the reactor. The reactor is the main research facility at the centre. It is a heterogeneous, swimming-pool reactor of the IRT type, which uses light water as a moderator, coolant and reflector. The fuel rods are UO_2 enriched to 10% in ^{235}U. The average thermal power obtained is 2 MW. The maximum thermal neutron flux at the centre of the active core is approximately 2×10^{13} n/cm^2 sec. There are eight radial horizontal channels, a thermal

column and a channel tangential to the core and separated from it by a lead shutter. Two of the horizontal channels are fitted with suitable filters in order to produce a relatively pure fast neutron flux, useful in radiation chemistry and biological work. There are also twelve vertical irradiation channels including a 23-mm dia tube passing through the centre of the active core, nine 52-mm dia tubes surrounding the core and two 180-mm dia tubes for the irradiation of large-volume samples.

15. Adjacent to the reactor tank a "hot cell" is provided for the purpose of transferring irradiated samples into it directly from the tank and through interconnecting pipeways. The "hot cell" is equipped with remote manipulators and machine tools for sample handling, and the operator views the inside through a lead-glass window shield.

16. A mechanical and an electrical workshop are attached to this Division.

17. Experimental work is being carried out in order to determine the important reactor parameters. The neutron flux is being mapped around the reactor core and in the experimental channels. These data are useful for the reactor users.

18. An analytical and chemical laboratory is being established for the purpose of studying reactor tank corrosion problems.

19. Future plans include modification and improvement of certain control systems and a possible reactor power upgrading.

Radioisotope Production Division

20. The radioisotope laboratory is to be used to produce short-lived radioactive preparations for medical, agricultural, industrial and scientific purposes. Raw materials are neutron-irradiated and the nuclear reactor facilities are used for this purpose. It is estimated that the annual production of this laboratory will be 300 curies and production should commence early in 1969.

21. The irradiated samples are transported via a conveyer drive down a production line consisting of seven "hot cells" and nine glove-boxes. The "hot cells" are equipped with remote mechanical manipulators, machine tools and other devices. Operators view the inside of the cells through lead-glass shields. The "hot cell" shielding allows work to be carried out with activities of up to 3 g radium equivalent (^{24}Na). Glove-boxes allow handling with activities of up to 100 mg radium equivalent (^{198}Au). The "hot cells" and glove-boxes are connected to a special ventilation system which expels the active air through a tall chimney stack. Special sewerage and efficient radioactive waste disposal facilities are provided.

22. Quality control and improvement of production is achieved by chemical analysis, emission spectroscopy and multi-channel pulse amplitude analysis for beta and gamma radiation. Absolute activity determinations can also be made by using coincidence and 4π counting techniques. The laboratory also has glass-blowing, photographic and mechanical workshop facilities.

23. Some of the short-lived isotopes that will be produced include ^{24}Na, ^{32}P, ^{131}I, ^{198}Au, ^{82}Br, ^{42}K, ^{64}Cu and ^{140}La. Other radioisotopes may be produced on request.

Physics Division

24. The primary interests of this Division are neutron-capture gamma-ray spectroscopy, neutron activation analysis, and neutron and X-ray diffraction from single crystals.

25. Semiconductor detectors operated at low temperatures are used together with scintillation and proportional radiation detectors.

26. Pneumatic tubes will be installed on one of the horizontal beam tubes to facilitate rapid activation analysis and the study of short-lived isotopes. Automatic preset control systems with recycling capability will be available early in 1969.

27. Both linear and logical electronic units are available together with a 4096 and 1024 channel pulse-amplitude analyser. High resolution spectroscopy requires a large number of data storage channels.

28. The automatic neutron-diffractometer has been ordered from Mitsubishi of Japan and will be installed in the middle of 1969. A taw-circle automatic X-ray diffractometer will be installed early in 1969.

29. The central electronics laboratory for the Nuclear Research Centre will be established within the Physics Division during the early phase of its development. This laboratory is now equipped to perform various kinds of specialized work, particularly in the field of nuclear electronics. The latest digital and analogue techniques are employed.

30. The data processing section will also be built up within the Physics Division. A medium-size high-speed digital computer will be installed during 1969. It is planned to carry out a number of experiments for on-line control with this computer system. The system will also be used in processing geological data, material stocks and library work. The scientific programming language available with the machine could be used for computation by workers within the Centre and those at other establishments.

The Geology Division

31. This Division is organizing a survey of radioactive minerals and nuclear raw materials in Iraq. Close co-operation is maintained with the Directorate-General of mineral resources and other Divisions within the Centre. For this purpose mobile drilling rigs, car-borne radiation detectors and portable scintillation detectors will be available. A good analytical laboratory for geochemical work will be equipped. Neutron activation techniques will be employed in the analysis of samples. A wide range of surveying equipment is available. Detailed work should commence in 1969.

Health Physics Division

32. This Division is responsible for the safe handling, storage and disposal of radioactive material. Monitoring of radiation levels within the laboratories is carried out and a personnel monitoring service is maintained. A nation-wide film-badge service has also been organized. A wide range of health physics instrumentation is used by this Division.

Biology and Agriculture Division

33. This Division is now actively engaged in work on the irradiation of dates for the purpose of sterilization and delaying ripening. The Division is equipped with a 12000-Ci cobalt-60 irradiator. It is also carrying out plant-water-soil relationship studies, with particular reference to local varieties of grains.

Maintenance and Engineering Services Division

34. This Division is responsible for maintaining all the necessary services in good working order and modifying them when required. The services include transportation, communications, an electrical substation, a water purification plant, a liquefier machine, a laundry service, a radioactive-waste burial station, ventilation, air-conditioning systems and the boiler house.

35. The main engineering and machine-tools workshops are operated under the direction of this Division. Extensive machinery is available at the machine shops.

The Library

36. The Nuclear Research Centre has an extensive library which receives nearly 150 current periodicals on atomic energy and related fields. A large collection of scientific books is indexed and kept available for the researchers. This is the only depositary library in the country for information relating to atomic energy. Microfilm records are kept and microfilm viewing equipment is available.

THE IRAQI CENTRE FOR CANCER AND ALLIED DISEASES

37. This Centre is nearing completion and it is expected that early in 1969 its various Departments and Divisions will be in operation. Among its facilities the most important ones are the following:

(a) The Radiotherapy Department, which will have an electron accelerator (6 MeV), a cobalt-60 unit (3000 curie) and two deep X-ray therapy units (each 250 keV);

(b) The Radioisotope Department;

(c) The Pathology Department;

(d) The Operation Theatre; and

(e) A special ward with 42 beds for patients receiving radiation treatment. A near-by hospital with 150 beds and an operation theatre will work in conjunction with the Centre.

38. When completed, the Ministry of Health will be in charge of the whole project and a convalescence home and cancer research laboratories will be added. The latter buildings will be financed by funds made available to the Iraqi Cancer Society by the Calouste Gulbenkian Foundation.

14. ITALY

The Main Developments in the Italian Nuclear Energy Programmes during 1968

GENERAL

1. At its eleventh regular session the General Conference was informed of the main developments in the Italian nuclear energy programmes which are described in document GC(XI)/INF/97/Rev.1, and considerable progress has been made since then in carrying out these programmes. The most important developments are described below.

PCUT PROGRAMME

2. The Trisaia Nuclear Research Centre of the National Nuclear Energy Commission (CNEN) near Rotondella (Matera province) was officially opened on 2 May 1968. Under the Uranium-Thorium Cycle Programme (PCUT), the Centre is required to carry out research with a view to developing:

(a) Knowledge concerning the technical possibilities and economic advantages of applying the uranium-thorium cycle to power reactors as an alternative to the uranium-plutonium cycle; and

(b) The techniques and technologies of reprocessing irradiated fuel and refabricating nuclear fuels by remote handling.

3. This research will be mainly carried out by the installation for the reprocessing and refabrication of fuel elements (ITREC) at the Trisaia Centre, and subsequently other installations will also be used for this purpose. In addition to its main aims mentioned above, the research also serves a number of purposes of secondary importance relating to various branches of engineering, chemistry and physics and the economic evaluation of the experimental data obtained. It should be noted that the criteria used in the design and operation of ITREC, which were established for experimental work on thorium fuel, can also be applied in the case of uranium-plutonium fuel, for which the requirements with regard to refabrication by remote handling are the same. Thus, once ITREC has completed the necessary study of the fuel cycle in converter reactors, it will be possible to use it for experimental work on fuel cycling in fast reactors.

EUREX PROGRAMME

4. The construction of the EUREX-installation at Saluggia, which began in January 1966, was completed in March 1968 and it is intended to start using this installation in early autumn.

5. The design, construction and use of this installation is part of the EUREX Programme, which envisages research on the reprocessing by aqueous techniques of fuel elements in research and power reactors. The CNEN intends to use this installation to study the technological and chemical problems bound up with reprocessing installations so as to obtain the technical and economic data required to construct an installation carrying out reprocessing on an industrial scale which would meet future national requirements.

PLUTONIUM PROGRAMME

6. At the Casaccia Nuclear Study Centre a laboratory has been constructed covering an area of almost 1800 m^2, half of which is intended to be used for small laboratories specializing in research on ceramic-plutonium materials.

7. In Italy the growing interest in plutonium as a nuclear fuel is justified by the fact that about 300 kg of this precious metal is produced per year, i.e. slightly less than one-third of a ton, in the nuclear plants now in operation. Furthermore, current estimates indicate that there will be a considerable increase in production in future years. These circumstances have prompted the principal Italian organizations interested in national nuclear energy development to undertake long-term development and research programmes relating to plutonium-based fuels.

8. The Ente Nazionale per l'Energia Elettrica (ENEL), in co-operation with EURATOM, has embarked on a series of studies and tests with a view to the immediate use of plutonium in thermal reactors; the tests consist of the irradiation of a large number of plutonium-based elements in an Italian nuclear plant. In addition, the CNEN has undertaken large-scale activities relating, inter alia, to the development of plutonium-based fuel elements for fast reactors.

9. The main aim of the Plutonium Programme, which started in 1966, is to enable the CNEN as quickly as possible — by providing it with the necessary technicians and equipment — to develop ceramic-plutonium nuclear fuels. The construction of the laboratory with an area of 1800 m^2, mentioned above, serves this purpose. The CNEN programme also includes irradiation tests with ceramic-plutonium fuel.

ROVI PROGRAMME

10. The Italian ROVI Consortium was set up in December 1967 under the auspices of the CNEN with a view to the commercial development and exploitation of ROVI reactors as desalting plants on both domestic and international markets. This Consortium includes the following seven major Italian industrial companies: Bombrini Parodi Delfino, Breda, FIAT, Montecatini Edison, Progettazioni Meccaniche Nucleari (IRI), SNAM Progetti (ENI), SORIN. The Board and Secretariat of the Consortium are appointed by the CNEN.

11. The present programme of work covers the preparation of a commercial tender, specifying the cost and providing for a guarantee, for a small plant which could produce about 50000 m^3 of desalted water per day. This tender should be ready by the end of 1968. Considerable interest has already been shown in this project by the authorities in the Italian regions in which water resources are scarce and by many countries, particularly developing countries.

12. The CNEN and the Italian firms in the Consortium believe that ROVI can make a vitally important contribution to the solution of the problem of water supplies in many areas of the world.

DEVELOPMENTS IN THE NATIONAL NUCLEAR ENERGY INDUSTRY

13. In March 1968 COREN, the nuclear reactor fuel company jointly established in July 1967 by Westinghouse, FIAT and EFIM-Breda, completed the construction of its installation at Saluggia and, at the end of April 1968, started the first operations connected with the assembly of the fifth core area of the pressurized-water reactor at Trino Vercellese.

14. The two other Italian companies which intend to manufacture nuclear fuel are FABBRICAZIONI NUCLEARI S.p.A. at Genoa, set up by Ansaldo Meccanico Nucleare and General Electric, and COMBUSTIBILI NUCLEARI S.p.A. set up by SNAM Progetti and the United Kingdom Atomic Energy Authority at Rotondella (Matera province).

15. JAMAICA

Summary of Activities in the Peaceful Uses of Atomic Energy

1. Functional studies of various organs in rats using ^{131}I.
2. Studies on insulin secretion from isolated rabbit pancreas.
3. Study of the insulin secretion capacity in malnourished infants.
4. Attempt to set up a radio-immunoassay for glucagon.
5. Attempt to prepare purified insulin-secreting tissue from mammalian pancreas.
6. Assay of hexokinase enzyme in normal and diabetic human red blood cells using radioglucose.
7. Studies of biosynthesis of natural products using radioisotopes.
8. Study of fatty liver formation using ^{14}C-acetate.
9. Study of muscle catabolism using ^{14}C-carbonate and ^{14}C-arginine.
10. Study of turnover of amino-acids and protein synthesis using ^{14}C-lysine.
11. Study of protein metabolism in humans using ^{75}Se-methionine.
12. Study of iron absorption using ^{59}Fe. Study of albumin metabolism using ^{125}I and ^{131}I.
13. Study of mineral nutrition in plants.
14. Therapy studies (Kingston Public Hospital) using ^{60}Co source.

16. JAPAN

Progress in the Peaceful Application of Atomic Energy during the 1967/68 Period

GENERAL

1. The long-range programme for the development and utilization of atomic energy was published by the Atomic Energy Commission in April 1967. The 1967-68 period was the first fiscal year[6] in the implementation of the programme. With a budget of $58 million, which is 38% higher than in the preceding year, the Government has stepped forward to a new stage. More than three thousand people are now working in governmental or quasi-governmental organizations concerned with nuclear energy.

NUCLEAR POWER

2. At present one commercial nuclear power plant is in operation and five are under construction. The status of these plants is indicated below.

3. According to the long-range programme it is foreseen that 6000 MW(e) of nuclear power plants will be built by 1975 and 30 000 to 40 000 MW(e) by 1985. Private electric utilities are active in nuclear power programmes, and steady progress has been made towards the target envisaged in the long-range programme.

4. Side by side with the nuclear power programmes of private electric utilities, the Government intends to play an active role in developing the fast breeder reactor on the one hand, and the heavy water reactor on the other, by designating their development as "national projects". In October 1967 the Power Reactor and Nuclear Fuel Development Corporation (PNC) was set up, incorporating the former Atomic Fuel Corporation as its nuclear fuel division. PNC has been entrusted with the design and construction of prototypes of a fast breeder reactor and an advanced thermal reactor, in addition to the functions taken over from the Atomic Fuel Corporation.

5. According to the power reactor development programme decided on by the Government in March 1968:

(a) Research and development on the fast breeder reactor, with mixed oxide fuel, will be carried out anticipating that an experimental reactor of 100 MW(e) will become critical in 1972, and subsequently a prototype reactor of 200-300 MW(e) by 1976; and

(b) Development of the heavy-water moderated, boiling-water cooled reactor is expected to lead to the building of a

Name	*Type*	*Location*	*Power (MW(e))*	*Date of entry into operation*
Japan Atomic Power Co.:				
The Tokai Power Station	Calder Hall	Tokai	166	July 1966
The Tsuruga Power Station	Boiling water reactor (BWR)	Tsuruga	322	December 1969
Tokyo Electric Power Co., Fukushima Nuclear Power Station, No.1	BWR	Fukushima	400	December 1970
No.2	BWR	Fukushima	784	May 1973
The Kansai Electric Power Co., Mihama Power Station, No.1	Pressurized water reactor (PWR)	Mihama	340	December 1970
No.2	PWR	Mihama	500	June 1972

6) The fiscal year in Japan starts on 1 April.

prototype reactor of 200 MW(e) by 1974. The fuel to be used for the reactor will be slightly enriched uranium or plutonium-enriched uranium at the initial stage, and natural uranium at a later stage.

6. Progress has been made with respect to the development of both types of power reactors:

(a) In August 1967 the Japan Atomic Energy Research Institute (JAERI) had made the first conceptual design of the fast breeder reactor and PNC, taking over the work done by JAERI in this specific field, completed the second conceptual design in May 1968. Research on reactor physics has been done by making use of a fast critical assembly built at JAERI in April 1968. Also, research and development on sodium technology, major equipment and components, mixed oxide fuel, safety, etc. in relation to the fast breeder reactor have been carried out jointly by PNC and JAERI; and

(b) As to the advanced thermal reactor PNC, through contracts with private industry, is making the detailed design of the prototype reactor which is to be based on the conceptual design already made by JAERI. In addition, the existing thermal loop has been improved in order to facilitate experiments on heat transfer, and work on making test fuel elements has made progress. In order to make the design more precise, PNC concluded a contract with the United Kingdom Atomic Energy Authority in February 1968 to obtain information on the enriched uranium steam-generating heavy water reactor.

7. Besides the development of these kinds of reactors, research and development on light water type reactors have also been carried out in order to accelerate manufacturing of these reactors by our own industry, and also to contribute to the improvement of this type of reactor. The materials testing reactor of 50 MW(th) which was completed in February 1968 at the Oarai Establishment of JAERI, will be used mainly for test irradiation of nuclear fuel and material for light water reactors.

NUCLEAR FUEL

8. The total amount of uranium required for nuclear power plants by 1985 will reach approximately 90 000 tons in terms of U_3O_8. In spite of the extensive exploration made by the Geological Survey of Japan and PNC, the total uranium ore reserve in Japan was estimated at about 10 million tons (only 5 300 tons in terms of U_3O_8) as of 1 April 1968. It is, therefore, of supreme importance for our nuclear fuel policy to secure a stable supply of uranium from abroad on the one hand, and on the other to make the maximum use of uranium by establishing the appropriate nuclear fuel cycle within this country.

9. In December 1967 and January 1968 electric power companies concluded long-term contracts to purchase 15 000 short tons of uranium, in terms of U_3O_8, from Canadian mines.

10. As to the reprocessing of irradiated fuel, PNC is planning to build a reprocessing plant with a capacity of 700 kg per day, and is reviewing the second detailed design. The plant is expected to start operation by 1971. In order to refine our technology in this field JAERI has established the Fuel Reprocessing Development Laboratory which, in May 1968, succeeded in extracting 18 grams of high-grade plutonium-239 from the fuel irradiated in the JRR-3 (natural uranium — heavy water reactor of 10 MW(th)).

11. Taking into consideration the prospect that accumulated plutonium from our nuclear power plants will amount to around 15 tons by 1980, and about 42 tons by 1985, development of the effective use of plutonium is also a major part of our nuclear fuel policy. In addition to the research facility at JAERI to develop plutonium fuel, PNC completed the Plutonium Fuel Development Laboratory in 1965 and is doing research and development on mixed oxide fuel. JAERI, in co-operation with private industry, is also undertaking research on plutonium carbide and plutonium nitride fuel.

12. As to the enrichment of uranium, PNC is carrying out research and development on the centrifugal separation method, and the Institute of Physical and Chemical Research, together with private industry, is doing research on the diffusion separation method. Basic research on the chemical separation method is also being done in the universities.

13. Fabrication of nuclear fuel is also one of the essential parts of the nuclear fuel cycle. Anticipating the rapid growth of nuclear power plants, five private companies have filed applications with the Government to obtain licences for nuclear fuel fabrication. The Atomic Energy Commission is working on safety criteria of fuel fabrication facilities, which will serve as a basis for safety review of these facilities.

14. As to the nuclear fuel policy, the Atomic Energy Commission has already laid down the basic policies in its long-range programme and, in order to elaborate the nuclear fuel programmes in more concrete form, has set up a Special Committee on Nuclear Fuel. The Committee produced its report in March 1968 after ten months' study of the subject.

NUCLEAR SHIP

15. The Japan Nuclear Ship Development Agency, the government corporation in charge of building our first nuclear ship, placed an order for the ship with private industry in November 1967.

16. The Agency also decided in November 1967 to set up an anchorage for the nuclear ship in Mutsu City, Aomori Prefecture. The Atomic Energy Commission has completed the safety review of the reactor to be installed in the nuclear ship.

17. The major characteristics of the nuclear ship are as follows:

Gross tonnage	8350 tons (23 000 m^3)
Displacement	10 400 tons
Service speed	16.5 knots
Complement	79 persons
Type of reactor	PWR
Thermal output	36 MW

USE OF RADIATION

18. Use of radiation has steadily spread in the fields of medicine, agriculture and industry. The number of installations using radiation increased from 1425 in March 1967 to 1540 in March 1968.

19. Development in this field during the 1967-8 period includes the development of an isotope-battery using strontium-90. The Takasaki Establishment of JAERI has promoted development in radiation chemistry, and in May 1968 succeeded in the trial production on an industrial basis by radiation of polymerized trioxan.

20. In the field of food irradiation the Atomic Energy Commission decided in September 1967 to carry out a co-ordinated project on food irradiation. The foods being treated in the project are potatoes and onions for inhibition of sprouting, and rice for insect eradication and disinfestation.

NUCLEAR FUSION

21. The Atomic Energy Commission set up the Committee on Nuclear Fusion to study the precise programme for the development of nuclear fusion. Based on the report of the Committee, the Atomic Energy Commission decided in July 1968 to start a co-ordinated project on nuclear fusion.

INTERNATIONAL CO-OPERATION

22. In 1968 bilateral agreements were concluded with the United States of America and the United Kingdom of Great Britain and Northern Ireland. According to the Japan-USA Agreement, enrichment services for 161 tons of uranium-235 will be provided by the USA.

17. LEBANON

Progress in the Peaceful Uses of Atomic Energy in 1967/68

1. Lebanon regularly receives from other countries radioisotopes, such as hydrogen-3, carbon-14, chromium-51 and iodine-131, which are mainly used in medical diagnosis and biochemical research. The American University and the French University have staff who specialize in the handling and use of these radioisotopes, and many medical doctors use iodine-131 in their private practice. The university hospitals also have a number of cobalt-60 bombs. In July 1968 a 4000-curie cobalt bomb was installed in the hospital attached to the Faculty of Medicine in the French University.

2. It should be noted, however, that Lebanon has neither a nuclear reactor nor a particle accelerator and that this places Lebanon at a great disadvantage from the educational point of view as compared with Egypt, Syria, Iraq and Israel, which have already received substantial assistance in cash and in the form of equipment from the International Atomic Energy Agency or private foundations. Experimental nuclear physics and the peaceful uses of atomic energy constitute a branch of knowledge which cannot be neglected in any university at present. In Lebanon higher education in the other branches of science certainly does not fall below the standard of that provided in countries at a comparable stage of development and there is no sound reason why it should lag behind in the case of nuclear physics, but the financial resources available do not permit the Government to bear the cost of the necessary installations itself. The Conseil National Libanais de la Recherche Scientifique therefore wishes to draw the attention of Member States of the International Atomic Energy Agency to the regrettable lack of funds for work in experimental nuclear physics in Lebanon.

18. MADAGASCAR

Progress in the Peaceful Uses of Atomic Energy - Work of the Radioisotopes Laboratory in 1967/68

1. The work of the Radioisotopes Laboratory covers two fields:

(a) Nuclear medicine,
under Dr. Manambelona;

(b) Isotopes in agriculture,
under M. Moutonnet, agricultural engineer from the Commissariat à l'énergie atomique (French Atomic Energy Commission).

NUCLEAR MEDICINE

2. The year 1967/68 has been mainly notable for the use made of the results of the work that has been done since 1965 when the Laboratory was officially opened. On this basis the following activities have been undertaken:

In the field of thyroid pathology

3. Statistical assessment of goitres endemic to Madagascar and analysis of causative factors responsible. The study has been based on patients attending the Laboratory and on school children at various convent schools.

4. We ascribe its endemic nature to a conjunction of three factors: iodine deficiency, the family structure and the influence of high altitudes on human biology. Collective prevention measures are currently under study in co-operation with responsible departments of the Ministry of Health.

In the field of liver pathology

5. A study of tropical cirrhosis has been initiated. We have drawn attention to the fundamental dif-

ference between the type of cirrhosis found in Madagascar and European cirrhosis.

The differences can be shown schematically:

(a) *Difference in scintigrams obtained using radioactive colloidal gold:*

European cirrhosis	*Tropical cirrhosis*
Moderate distension of the spleen	Enormous distension of the spleen
Frequent osseous fixation	No osseous fixation

(b) *Aetiological difference:*

Generally alcoholic origin	Parasitic origin (malaria, bilharzia, intestinal worms).

Mineral analysis of water used for consumption

6. A mineral analysis of water samples taken in the dry season from different points in the island has been undertaken at the Laboratory with a view to finding factors correlating with certain endemic diseases (deficiency diseases of various kinds, endemic bilharzia).

7. It will soon be possible to draw up a map showing the distribution of elements playing an important part in biology, e.g. calcium. It should then be possible to see whether or not there exists a correlation between the map and biological indications of diet deficiency in the element under examination (e.g. for calcium, dental decay or possible tendency to convulsions). The results already obtained seem to account for the endemic nature of spasmophilia (tendency to convulsions) in the Fianarantsoa and Ambositra zone.

8. Finally, to facilitate the exchange of views and co-operation with provincial hospitals we have organized in certain important centres like Tulear and Fianarantsoa lectures illustrated by slides and films obtained from the Commissariat à l'énergie atomique. These lectures were for members of the medical profession. In the lectures we particularly emphasized the important results of work undertaken at the Laboratory on certain diseases native to Madagascar. The lectures have generally been followed with much interest.

Research contract concluded with the Agency

9. Our study on the life span of erythrocytes in patients suffering from glucose-6-phosphate-dehydrogenase (G.6.P.D.) deficiency will be completed this year.

ISOTOPES IN AGRICULTURE

10. The Laboratory's activity in this field is carried on along two lines: study of water content in soil using neutron probes (our main activity) and our own contribution to agricultural entomology. It is divided into laboratory and field work; field work is carried out at many different points on the island, particularly close to the west and north west coasts.

Laboratory work

11. The Laboratory has set up further sampling points for testing the water content of soil and has initiated a comparative study of neutron measurement of real evapotranspiration and the values obtained by the Prescott formula, as well as beginning work on the calibration of surface probes.

12. Study of ignition losses in soils and kinetic study of the desaturation profile based on the soil at the Laboratory.

13. Calibration of neutron moisture meters on the basis of soils from the Mangoky delta; volumetric calibration of depth probes, on the basis of four soils of differing density.

14. Agricultural entomology. Labelling the larvae of sugar cane locusts by ^{32}P injection in the cane shoots; labelling of adult earias by ^{32}P and ^{35}S injection.

Field work

15. *At Tafaina* (a catchment area selected for study by the French Office for Overseas Scientific and Technical Research). Developing a surface probe with scaled-down head for measuring soil water content during rainfall and studying how it varies as a function of run-off. Installing a new tube, 6 m long, in a second run-off test plot with a steep slope. Water profile, recorded twice monthly.

16. *At Manankazo.* Installation of four tubes, on-the-spot calibration. Water profile recorded (every 15 days during the rainy season). Measurements taken during the dry season; initial tests for determining root activity in pine trees by localized application of ^{32}P and measurements of leaf radioactivity.

17. *In the Mangoky delta* (where cotton growing has been introduced on a large scale). Installation of between 50 and 60 tubes completed in December. Analysis of results to obtain partial and total volumetric humidity. Water profiles recorded every 10 days: before irrigation and 48 hours after. Neutron measurements programme during irrigation season.

18. *At Tanadava.* Installation of a 310 probe has been set up to study cotton boll shedding as a function of soil water content. The study had to be broken off, as the results were distorted by severe weather.

19. *At Ambilobe* (sugar cane cultivations). Installation of a probe. Dry-season measurements on a group of six tubes.

19. MOROCCO

The Applications of Nuclear Techniques in Morocco

PAST ACHIEVEMENTS

Development of prospecting for radioactive materials in Morocco

1. A considerable amount of prospecting for radioactive ores has been carried out in almost the entire southern area and in the western and eastern parts of the northern area of Morocco. Between 1946 and 1950 the prospecting was carried out by the Service d'Etudes des Gîtes Minéraux of the Direction des Mines et de la Géologie and the French Atomic Energy Commission and, from 1953, by SOMAREM, a joint company formed by the Bureau de Recherches et de Participations Minières and the French Atomic Energy Commission. In all the areas in question promising results were obtained and the phosphates in Khouribga and Youssoufia, which were the subject of very detailed study, were of particular interest.

Nuclear techniques and their applications in Morocco

2. The specialized services in Morocco have adequate equipment and staff to carry out all the prospecting for radioactive ores which has been undertaken. The Direction des Mines et de la Géologie already has eight GM-SRAT counters and three scintillometers for use in a chemical analysis laboratory.

3. The extremely satisfactory results obtained in the peaceful uses of atomic energy in the highly industrialized countries fully warranted the wider use of nuclear techniques in those sectors of the Moroccan economy which could benefit from them. With that end in view, an expert (Mr. P. Delattre) was sent to Morocco in 1961 in response to a request by the Government. On completion of his assignment, he prepared a report setting out a programme for the possible development of the peaceful uses of atomic energy in Morocco, particularly with regard to the following subjects: geology and hydrology; medicine and biology; agriculture; industry and electric power; and training.

CURRENT SITUATION: WORK DONE AND POSSIBLE USES OF NUCLEAR TECHNIQUES

4. Mr. Delattre's proposals cover various activities and constitute an integrated programme based on the requirements and resources of the country. The equipment used makes it possible, to a great extent, to perform the basic work which is a prerequisite for carrying out most of the activities relating to fields in which the use of nuclear techniques offers certain advantages.

Thermal energy

5. Although the thermal energy requirements are not very great, the Office Chérifien des phosphates expressed the desire in 1957 to use a nuclear reactor to dry phosphate from the Khouribga deposit. It was decided recently to go ahead with this project and it seems that it could be carried out satisfactorily by using nuclear energy.

Industry

6. Although industrial activities varied in character to an appreciable extent, they mainly consisted of the manufacture of elementary products in which conventional techniques were adequate. Industrialization is now under way and it may be possible to achieve worth-while results by using radioisotopes for the following purposes:

(a) The measurement of the carbon/hydrogen ratio and the sulphur content of hydrocarbons in the oil-refining industry;

(b) The detection, by means of radioactive tracers, of leaks in water-supply circuits and pipelines carrying mineral-oil products or gas;

(c) Chemical analysis by isotopic dilution;

(d) The measurement of soil-moisture and the density of concrete and soil; and

(e) The sterilization of fresh fish.

Geology

7. The geological research carried out showed that it was important to use modern techniques which facilitate prospecting for ore and oil. The laboratories of the Direction des Mines et de la Géologie are now using some unsophisticated instruments to measure radioactivity in prospecting for radioactive materials, and isotopic methods are still used to determine the age of rocks. The main laboratory, at Rabat, has the following equipment: one radiation diffractometer, one spectrograph, one polarograph, two G.M.T. 3 T gammameter sets, two G.M.T. 15 T gammameter sets and two SPAT/3-type scintillation radiometers.

Medicine and biology

8. The hospitals in Casablanca and Rabat are the main users of atomic energy and radioisotopes for medical purposes. The Bérgonoé Centre, the only existing centre for cancer treatment, which is in the Avéroés Hospital, Casablanca, is equipped with a scintigraph, a counting assembly and a cobalt bomb which are operated by two qualified radiologists. In the Avicenne Hospital, Rabat, there is an isotopic diagnosis centre, equipped with four groups of counters and one scintigraph, which is under the direction of a medical doctor specializing in the use of isotopes, assisted by two pharmacists.

Agriculture

9. Agriculture covers a very wide field and has a preponderant place in the national economy. The use of modern techniques has helped to improve plant varieties and to protect crops from noxious insects and certain diseases. The scientific research facilities are concentrated in the Institut National de la Recherche Agronomique (INRA) and the experts working there have devised and carried out experiments relating to:

(a) The measurement of labile phosphorus which can be taken up in 12 types of Moroccan soil, using ^{32}P;

(b) The measurement of soil moisture, using a neutron probe;

(c) The labelling of punaise insects, which feed on cereals, and their parasites, Eurygoster, for the purpose of studying population movements (^{32}P and ^{59}Fe);

(d) The study of phosphorus exudation through the roots of some leguminous plants;

(e) The study of the development of the primary root system of the cork-oak; and

(f) The study of the possibilities of labelling migratory locusts.

University and technological training

10. To enable different bodies to carry out the research work undertaken, the Government has awarded fellowships to a large number of students so that they could specialize in the study of nuclear techniques in the main European universities. In this connection the Faculty of Science at Rabat also conducts supplementary training courses and arranges for students to attend courses held abroad.

DETERMINATION AND IMPLEMENTATION OF A NATIONAL POLICY ON THE PEACEFUL USES OF ATOMIC ENERGY

Establishment of an inter-ministerial committee

11. In view of the importance of the applications of nuclear techniques which are of interest to many bodies and services attached to different Ministries, the State has considered it necessary to set up an inter-ministerial committee to serve as the senior body responsible for promoting and co-ordinating the development of the uses of atomic energy for peaceful purposes.

Functions of the committee

12. The committee is required to promote all programmes for using atomic energy and to ensure that they are carried out and co-ordinated, particularly when they relate to training, health, agriculture, industry, geological and ore prospecting and scientific research. It will have to examine and supervise all programmes for using atomic energy in the public and private sectors and to decide on the advisability of carrying out work involving the use of nuclear techniques. The committee is provided with secretarial staff by the Minister for Industry and Mining who is responsible, inter alia, for contacting the

departments concerned, arranging for working meetings and joint visits, preparing draft regulations and legislation relating to atomic energy and drawing up a plan for training.

13. Mr. Majid Ahmed, who is head of the Service de l'Energie et des Etudes Minières and chief mining engineer in the Direction des Mines et de la Géologie, is entrusted by the Minister for Industry and Mining with the task of ensuring that the necessary studies are carried out and the necessary contacts made with a view to drawing up, in agreement with the relevant services of public departments and private bodies and with the assistance of the IAEA, basic legislation and regulations and an integrated programme relating to the domestic use of atomic energy.

POTENTIAL DOMESTIC USES OF ATOMIC ENERGY, AND RELATED PROJECTS

14. At the preliminary meeting held on 3 April 1968 in connection with the mission undertaken by Mr.Lloyd, Acting Director of the Programme Division of the Department of Technical Assistance of the IAEA, the committee for co-ordinating technical assistance made a systematic analysis of the programmes carried out with the assistance of the IAEA and selected the projects listed below.

Cobalt therapy and diagnosis, using radioisotopes (health)

15. This project relates to the establishment of a cancer treatment centre, near the Avicenne hospital, equipped with an isotope treatment facility and a cobalt bomb, together with a betatron, and the provision of complementary equipment for the isotopic diagnosis centre in Rabat.

Research relating to plant physiology (agriculture)

16. This project relates to the provision of the equipment to be used in the INRA in research on labile phosphorus, the labelling of insects, water utilization and evapotranspiration, and the determination of moisture by radiation.

Prospecting for uranium in ores (mining)

17. Under this project the IAEA would bear the cost of an expert's services for a period of 12 months.

Nuclear physics laboratory (Faculty of Science)

18. This project relates to the purchase of equipment for use in the laboratory engaged in practical work on nuclear physics at an estimated cost of $20 000, secondly, the payment by the IAEA of the cost of an expert's services under the 1967 programme which provides assistance to the Faculty of Science for research on plant physiology, and thirdly, training fellowships for assistants on the staff of the Faculty of Science.

19. The foregoing are all the projects envisaged at present, for which assistance is requested from the IAEA.

20. The projects which were accepted by Mr.Lloyd, Acting Director of the IAEA Programme Division, on 6 April 1968 at a working meeting with the committee for co-ordinating technical assistance are listed below.

Provision of assistance to the inter-ministerial committee on atomic energy

21. The IAEA will appoint an expert before the end of 1968 for a period of four months. His main duty will be to assist the secretarial staff of the inter-ministerial committee on atomic energy in drawing up a list of current users of atomic energy, organizing technical services, working out a five-year programme of operations and preparing the draft constitution of the body responsible for carrying out that programme.

Extraction of uranium from phosphates

22. An expert is to assist the responsible officials of the Bureau de Recherches et de Participations Minières in studying the possibilities of extracting uranium from phosphates in Morocco.

Fellowship awards

23. The request made by the Faculty of Science for three fellowships to be financed by the IAEA from funds available in 1968 has been approved. Three candidates have been designated to undergo specialized training in foreign institutions.

IAEA-INRA research contract

24. Under the IAEA research contract programme the INRA submitted a request for assistance in respect of a project relating to "the applications of

radiophosphorus in studying the physiological role of perennial plants grown in Moroccan soil", and this project has been found acceptable in principle.

25. With regard to the other projects envisaged, such as those relating to the determination of moisture by radiation and the labelling of insects, it has proved impossible to arrange for the provision of an expert specialized in all the subjects in question. Mr. Lloyd suggested, however, that the agricultural expert who will be sent to Morocco under the IAEA technical assistance programme should look into the matter and study the possibility of providing the INRA with advisory services.

26. With regard to the solid-state physics project to be carried out by the Faculty of Science at Rabat, it is foreseen that Mr. Berrade will work on his thesis abroad, using a fellowship which will be awarded to him, and that it would be possible to request the services of an expert for six months in 1970 under the United Nations Development Programme and to provide the necessary equipment at a cost of $7500.

20. NEW ZEALAND

Peaceful Applications of Nuclear Energy: 1967/68

NUCLEAR POWER

1. The planned introduction of nuclear power into New Zealand is still envisaged for about 1977. A unit rating of approximately 250 MW is considered to be appropriate for the New Zealand system as it will be at that time, with three similar units following at yearly intervals. Larger units will be acceptable for later stations, thus giving the acknowledged advantages of scale.

2. The report of the Planning Committee on Electric Power Development in New Zealand, which incorporates the above statement, points out also that if present investigations prove that large-scale reserves of natural gas are present in or around New Zealand, this could have an effect on the programme for the introduction of nuclear power. In the meantime, however, preparations for nuclear power generation are continuing as planned.

3. Site investigations in the Kaipara Harbour area in the upper North Island are continuing, adequate cooling water is available and the results of foundation investigations appear reasonable. This is the most favoured site, near the load centre of Auckland City, where there is a high demand.

4. Other aspects of the introduction of nuclear power which have been receiving attention are the establishment of safety criteria and consideration of licensing arrangements.

CENTRAL AUTHORITY

5. The New Zealand Atomic Energy Committee, responsible for advising the Government on these matters, has completed and presented to the Government its recommendations on the future organization and role of a central authority, to deal with nuclear matters in general and licensing and inspection of power reactors in particular.

6. Training programmes for specialized personnel continue, though difficulties are still being encountered in obtaining the type of personnel with the required background and experience.

HEALTH AND SAFETY CRITERIA

7. The Department of Health, through its National Radiation Laboratory, has spent a considerable time in the period under review assisting with the preparation of safety criteria for the siting of power reactors. This Laboratory has also statutory obligations in relation to the importation, distribution, installation, operation or use of radioactive substances or radiation producing devices. It issues required licences to specific personnel, whether they be employed within industry, government departments or the hospitals and medical profession. The Laboratory provides a free film badge service for the whole country, and it is the agency through which all radioactive sources are imported into the country. It maintains a register of the location and usage of such substances and radiation producing devices, also carrying out inspections at regular intervals.

8. The monitoring by the Laboratory staff of occupational radiation exposures of workers in the field covers 3091 workers, of whom 1262 are continuously monitored and 1829 workers are periodically monitored. As well as the supply of therapeutic applicators, primary X-ray standards are maintained, calibrations made, advisory services provided, educational and specialized training courses given and a

research and development programme undertaken. Environmental radioactivity measurements, involving the measurement of radioactivity in air, rain and milk, are undertaken on a continuous basis and the results published in a quarterly report. Nuclear testing in the Pacific has added considerably to this work.

CENTRAL NUCLEAR LABORATORIES

9. The Institute of Nuclear Sciences in the Department of Scientific and Industrial Research has extended its programme of work in a number of fields, but principally in the use of the 3-MeV Van de Graaff accelerator and in radiation chemistry.

10. More effort is to be put into the application of radioisotopes and radiation in the industrial field. The demand for this type of work is growing and in most cases the requirement is beyond the facilities available in industry itself.

11. A recent development produced excellent results as a particle and fibre abrasion tester. A radioactive stainless-steel Waring Blender blade has been used to develop a reliable abrasion test method. This has been used on wood fibre and clay fillers used in paper making. A good correlation has been obtained between abrasion values using this method and experimental paper cutting tests. The method has been shown to be more reliable and of wider application than the Valley Abrasion tests at present used in the paper industry.

12. As well as the normal nuclear physics experiments and studies, the accelerator has also been used to produce neutrons via the (d,t) reaction, the resultant neutrons being used to study neutron-induced reactions. In this way the reaction $^{82}Se(n,p)\,^{82}As$ has been used to study some of the properties of ^{82}As. The $^{12}C(d,n)\,^{13}N$ reaction was successfully used to produce sufficient amounts of ^{13}N. This isotope has been used by plant physiologists for investigating the uptake of nitrogen by trees.

13. Radiation chemistry work, both basic and applied, is beginning to open up in new avenues. Work on the reactions of peroxy radicals has continued. Several methods of identifying the acid formed during the gamma-radiolysis of oxygen-saturated solutions of methanol in water are being tried. The most promising method appears to be isotope dilution using ^{14}C-labelled methanol.

14. Experiments with a crosslinking agent and tallow, gamma irradiated, have produced a product which does not melt at 200°C (normal melting point 40°C). The mechanism of this reaction is at present under study.

15. Irradiation studies have commenced in an endeavour to extend the shelf life of Tamarillos (a New Zealand fruit). Various seeds for growth rate experiments and commercial preparations of enzyme catalase have been irradiated to inactivate viruses. Methyl methacrylate has been irradiated, testing its suitability as a stable dosimeter for electron beam irradiations in the megarad range.

16. Hydrology studies continue. Rain water samples from Malaysia and Thailand are being measured for tritium content. This is being undertaken at the request of the Agency. Ocean circulation studies are being maintained and measurements of ^{14}C in atmospheric CO_2 and in sea water bicarbonate continue.

FORESTRY RESEARCH

17. The Forest Research Institute is actively using radioisotopes in tree nutrition studies, tree physiology, forest pathology and for the study of weed control in forest nurseries.

DAIRY RESEARCH

18. The New Zealand Dairy Research Institute in the main uses ^{14}C for research on the metabolic activities of micro-organisms or the biosynthesis of milk components. Being on the same campus as Massey University and the Veterinary School, with the Plant Chemistry and Grasslands Division of the Department of Scientific and Industrial Research nearby, enables the various organizations and departments to assist each other in the maximum utilization of new knowledge and facilities available.

AGRICULTURAL RESEARCH

19. The Department of Agriculture and the Scientific and Industrial Research Laboratories are calling into use more radioisotopes as tracers in various animal studies and to solve nutritional and soil problems.

20. Nutritional studies in fruit research, plant chemistry, nitrogen fixation in soil, the use of radioisotopes in entomology and similar problems which affect New Zealand's primary industries are receiving more attention.

21. Special courses on radiation biology have been commenced for veterinary science students, and there is a stronger tendency for co-operative research between organizations that are in the position of being able to interchange limited manpower and equipment to greater advantage.

22. Cell biology is receiving more attention at the universities. Radiophysics and radiochemistry are being strengthened.

TRAINING

23. Most New Zealand universities provide seminars, training and research in nuclear physics, isotope or radiation chemistry and engineering. The Electrical Engineering Department of the Canterbury University has, as part of its equipment, a sub-critical nuclear assembly, which is used for the training of students studying various nuclear topics.

24. Although the nuclear laboratory of the Department is not equipped to support research, equipment is assembled to aid research where this does not interfere with the primary training role of the laboratory.

25. A current research project is aimed at the full simulation of various types of reactor on the Department's hybrid (analogue plus digital) computer, to permit investigations into instrumentation and control of these various reactor types.

MEDICAL

26. Our Medical School, in addition to training research students in isotope techniques and providing experience in the handling of radioactive substances, concentrates, in the Department of Biochemistry, on three main fields of work: the mechanism and replication of deoxyribonucleic acid (DNA) in micro-organisms and in bacteriophage; studies of the nucleotide sequences in the DNA of bacteriophage; and studies of the metabolism of carbohydrates and sugar alcohols by micro-organisms.

27. More therapy units have been installed or replaced in the major hospitals in New Zealand. In general the medical diagnosis and therapy facilities are of a very high standard.

28. Because of the geographical location, some of our hospitals are probably the most distant users of radioisotopes in the world, considered in relation to their distance from the usual commercial suppliers. All our hospitals, laboratory research workers and the industrial application field suffer from the lack of easily obtained short-lived radioisotopes. If current proposals for a research reactor are proceeded with, this will help overcome the situation felt, in the main, most severely in the medical field.

21. PAKISTAN

INTRODUCTION

1. The Pakistan Atomic Energy Commission (PAEC) is charged with the development of the nuclear power programme and the application of radioisotopes and radiation in medicine, agriculture and industry. It has pioneered the application of newly developed techniques involving the use of nuclear radiation and radioactive isotopes in medicine, agriculture, industry and research. The highlights of PAEC achievements in different fields are given below.

NUCLEAR POWER

2. Construction is under way of a 137-MW(e) nuclear power station at Karachi. Work is on schedule and the plant is expected to become operative in 1970.

3. The establishment of another nuclear power plant at Rooppur in East Pakistan is also being planned. It is proposed to have two units of 200 MW each, with the first expected to go into operation in 1974 and the second during the Fifth Plan period 1975-80.

AGRICULTURE

4. Important development work in agriculture is being carried out at the Atomic Energy Agricultural Research Centre, Tandojam, and at the Atomic Energy Centre, Dacca. Improved varieties of certain food and cash crops have been evolved. Efficiency of fertilizer applications has also been studied and practical recommendations made.

5. Two institutes for work on pest control and preservation of food by the use of radiation are being planned for the two wings of the country. These institutes (named IPCORI) are being established for disinfestation of stored food grains, pasteurization of fresh fruits and perishable foods and sterilization of medical supplies.

6. On the basis of encouraging results obtained by PAEC scientists in the evolution of new and better strains of jute, cotton, wheat and rice by gamma irradiation, it has been decided to establish two institutes exclusively for work on genetics and plant breeding, one at Lyallpur in West Pakistan and the other at Mymensingh in East Pakistan. The Lyallpur Institute is almost complete, while the Mymensingh unit is rapidly going up.

HEALTH

7. Atomic Energy Medical Centres using radioisotopes and radiation in diagnosis and therapy are in operation at Karachi, Dacca, Lahore and Jamshoro. The Centre at Multan is expected to go into operation very shortly. Two more Centres are under construction at Chittagong and Rajshahi.

8. The Medical Centres have proved of great help in the effective diagnosis and treatment of a number of malignant diseases like cancer and leukaemia. So far more than 14 000 patients have received radioisotope treatment at these Centres.

INDUSTRY

9. Many useful gadgets and instruments for scientific and general use have been designed and fabricated on a laboratory scale in the Atomic Energy Centres at Lahore and Dacca. The instruments have wide application in research, while some of the gadgets, consisting of electronic traffic-flow analyser controls of traffic signals, seed counting machines, etc., can be of great practical use.

10. Application of radioisotope techniques to hydrology and industrial problems is also under development. PAEC is collaborating with the Karachi Port Trust in undertaking a systematic survey of the silt movement near the harbour, using radioisotope tracers. In East Pakistan, the Water and Power Development Authority has been assisted in investigations on underground water movement.

11. The Lahore Atomic Energy Centre has also initiated work on harnessing solar energy for such small-scale but important uses as rural lighting, running low-power irrigation pumps in villages and small, family-size solar stills to convert brackish or saline water into fresh water.

RESEARCH AND DEVELOPMENT

12. In order to support the practical applications of atomic energy, considerable research effort is also necessary. Accordingly, a national multi-discipline institute for advanced studies is nearing completion in Islamabad. This is the Pakistan Institute of Nuclear Science and Technology (PINSTECH) whose principal facility is a 5-MW swimming-pool type reactor. Apart from being the first and only research complex of its kind in the country, PINSTECH has also started production of certain short-lived radioisotopes for consumption in the country.

13. The Atomic Energy Centres at Lahore and Dacca are also engaged in fundamental and applied research in atomic energy and allied fields.

SEARCH FOR NUCLEAR MINERALS

14. For making our nuclear power programme self-sufficient, it is essential to exploit local deposits of uranium and other nuclear minerals. The geologists of PAEC have discovered radioactive and heavy minerals in sizeable quantities in certain areas. The chemical and economic evaluation of the ores is in progress.

ADVANCED TRAINING

15. Realizing the importance of trained manpower for the success of any new development activity, PAEC had started its training programme from the very beginning. This foresight has paid rich dividends and PAEC has now on its rolls nearly five hundred qualified scientists, engineers and other technical persons whose services will be fully utilized in a number of new projects and plants under execution.

22. PHILIPPINES

Progress in the Peaceful Applications of Nuclear Energy during the Year 1967/68

GENERAL

1. The Philippine Atomic Energy Commission (PAEC) marked the tenth anniversary of its establishment on 16 July 1968. In general, the year 1967-68 was marked by a continued expansion of nuclear energy activities. This brief report summarizes the progress made, especially as it relates to the activities of the Agency.

NUCLEAR POWER DEVELOPMENT

2. The Manila Electric Company (MERALCO), the largest private electric utility company in the country, which serves the Manila metropolitan area, has analysed and evaluated the international bids received for oil-fired and nuclear-fuelled power plants in the size range of 300 to 500 MW(e). Although the economic competitiveness of the nuclear plants as alternatives to oil-fired plants was established from the analysis of these bids, the high capital cost of the former seems to have deterred MERALCO from adopting nuclear power for its generating units which are scheduled for operation in 1971-73. MERALCO's tentative plans now indicate the operation of its first nuclear plant by 1975-77.

3. Although the National Power Corporation has not formulated any definite plan for nuclear power development, it has started studies of the possibility and implications of installing nuclear plants to complement its existing hydro plants in Luzon.

4. To pave the way for the eventual introduction of nuclear power in the country, the following have been undertaken through the initiative of PAEC:

(a) The Atomic Energy Regulatory and Liability Act, which provides the legal framework for the licensing and regulation of atomic energy facilities and the use of materials, and establishes the rules on civil liability for nuclear damage, was enacted by the Philippine Congress during its 1968 regular session;

(b) A new Agreement for Co-operation between the Philippines and the United States of America Concerning the Civil Uses of Atomic Energy was concluded, providing for the uranium materials needed during the next 30 years in the operation of two nuclear power plants having a capacity of 300 to 500 MW(e) each; and

(c) The local training programme in reactor operation, maintenance and instrumentation has been finalized to provide initial training for the engineering staff of MERALCO and the National Power Corporation.

THE AGENCY'S REGIONAL TRAINING COURSE ON PLANNING FOR THE HANDLING OF RADIATION ACCIDENTS

5. PAEC acted as host to this brief course which lasted from 2 to 13 October 1967. The course provided training for 19 nuclear scientists, all of whom are responsible for the handling of radiation accidents in the seven Asian countries that they represented. An international team of seven visiting professors was assisted by six Philippine lecturers in the conduct of the course. The head of the Health Physics Department, Philippine Atomic Research Center (PARC), served as course director.

INDIA-PHILIPPINES-AGENCY (IPA) NEUTRON CRYSTAL SPECTROMETRY PROGRAMME [7]

6. This five-year research and training programme has entered its fourth year of operation. Two participants, one from the Republic of Korea and the other from Thailand, completed their training during the period under review. Two Indian experts recruited by the Agency also completed their tour of duty. Meanwhile, a new group of three IPA participants from China, Indonesia and the Republic of Korea started training at PARC towards the end of 1967.

7. Apart from the noteworthy research being carried out under the IPA programme, a far-reaching result of this co-operative venture is the upsurge of interest and activity in neutron solid-stage physics

7) Under the agreement reproduced in document INFCIRC/56.

in the region. The Republic of Korea and Thailand are now doing neutron scattering research under the leadership of the scientists who have been trained under the programme.

8. The Joint Committee for the IPA programme held its fifth meeting at PARC in Quezon City. With the IPA agreement due to expire by the end of 1969, the future of the programme was discussed. Experience gained under the programme has served to focus attention on the need for expanding regional co-operation to meet the increasing quantity and sophistication of research on neutron scattering in the region.

SAFEGUARDS TRANSFER AGREEMENT

9. On 13 June 1968, the Governments of the Republic of the Philippines and of the United States of America signed a new Agreement for Co-operation Concerning the Civil Uses of Atomic Energy, which supersedes the Agreement signed on 27 July 1955. The new Agreement covers a period of 30 years and provides, among other things, for the transfer of up to 17 600 kilograms of enriched uranium in anticipation of the plan to introduce nuclear power into the Luzon Grid by 1975-77. The stipulated amount represents the requirements for two power reactors in addition to the modest requirement for research.

10. The two Governments further agreed that the Agency should continue to administer the safeguards stipulated in the new Agreement for Co-operation, as was done under the Agreement that has been superseded. Accordingly, a new trilateral agreement on the transfer of safeguards between the Agency, the Philippines and the United States of America was signed on 15 July 1968[8]. The Agency is at present preparing the text of the subsidiary arrangements to this new Safeguards Transfer Agreement in accordance with its Safeguards System.

IAEA RESEARCH CONTRACTS

11. The Philippines continued to avail itself of Agency research contracts as a means of stimulating local research activities in the nuclear field. Contracts totalling $20 700 were awarded for one new project (mutation studies of soybeans, with the Agency contributing $4 000) and five old ones (renewals). Of these contracts, four were awarded to PARC, one to the Philippine Women's University and the other one to the National Institute of Science and Technology. The research contracts renewed and the corresponding grants by the Agency were:

(a) Studies on the nutrition of coconut palm, $3300;

(b) Radioisotope studies in schistosomiasis, $1600;

(c) Effects of ionizing radiation on mango, banana and chico fruits, £4800;

(d) Co-ordinated programme on the use of induced mutations in rice breeding, $4000; and

(e) Co-ordinated programme on the study of protein metabolism in marginal protein deficiency, $3000.

TECHNICAL ASSISTANCE

12. For the past eight years, the Agency has been the Philippines' major source of technical assistance in atomic energy. In addition to the research contracts, assistance has been in the form of expert services, equipment grants and training fellowships. During the past year two experts, representing nine man months of expert services, were provided by the Agency for the IPA programme and the radioisotope production project. Equipment worth $14 000 for radioisotope production was also received. Ten new fellowships and one scientific visit were included in the 1968 programme of technical assistance.

13. As a result of the Agency's assistance, the production of 17 types of radioisotopes at PARC has been expanded, and superphosphate labelled with ^{32}P is now produced in quantities sufficient to meet local research requirements.

REPLACEMENT FUEL ELEMENTS FOR THE PHILIPPINE RESEARCH REACTOR PRR-1

14. All 20 new fuel elements have been received from the fabricator in the United States of America. The enriched uranium (93% ^{235}U) for these replacement fuel elements was supplied by the Agency under the offer made by the United States Government to donate $50 000 worth of special nuclear materials in 1966. With the reactor fuelled with the original 30 elements (containing uranium enriched to only 20%) at the end of its operational cycle, the first refuelling operation is now in progress. Earlier, the ^{235}U content of each fuel element was determined experimentally. Differences between the

8) Reproduced in document INFCIRC/120.

experimental values and the manufacturer's values ranged from 2.2% for high-load elements to 3.7% for low-load elements.

15. The fabrication of the third batch of ten replacement fuel elements is now under negotiation; the uranium is to be supplied through the Agency by the United States Government under a new Supply Agreement recently concluded between the Agency, the United States of America and the Philippines[9].

NON-PROLIFERATION TREATY

16. The Philippines was among the first Member States to sign the Treaty on the Non-Proliferation of Nuclear Weapons. The Philippine Ambassador to the United States and Permanent Representative to the United Nations signed the Treaty in Washington when it was first opened for signature on 1 July 1968, and later in Moscow. This is a manifestation of the strong support that the Philippines has accorded to the Treaty.

23. SAUDI ARABIA

In reply to the Director General's invitation to communicate a statement, the Government of Saudi Arabia has informed him that "we are still in the planning stage of atomic energy and we have not yet done any application in this field."

24. SOUTH AFRICA

Nuclear Activities in 1967/68

INTRODUCTION

1. The general theme of the South African nuclear research programme and the facilities established for its execution were set out in a similar document for the eleventh session of the General Conference in 1967[10]. What follows here is therefore a brief summary of advances and developments which have taken place during the past twelve months.

NUCLEAR POWER

2. After a study lasting some two-and-a-half years the report on the introduction of nuclear power in South Africa, prepared by the Atomic Energy Board working closely with the Electricity Supply Commission and various appropriate government departments, has been completed. The main conclusion reached was that nuclear power would be economically competitive in the Republic during the first years if a station with an output of between 200 and 350 MW were to be put into service in the Western Cape between 1978 and 1980.

3. The most suitable natural-uranium type for local conditions is at present considered to be one using heavy water as moderator and coolant. Since South Africa has no uranium enrichment plant, only those types of reactor fuelled with natural uranium were considered. South African industry should be able to supply up to two thirds of the material and equipment required for the first nuclear power station. The possible use of nuclear power for the desalination of sea-water was also studied, but it was concluded that there was no region in South Africa where fresh water produced in this way could compete in price with natural water for many years to come.

NUCLEAR MATERIALS

4. The Bufflex process for the production of high-grade concentrates from uranium ore, which was successfully developed a year or more ago and which is now being exploited on a commercial scale, entailed an ion-exchange step followed by solvent extraction. A further refinement known as the Purlex process is the elimination of the ion-exchange stage, and this is a project which has made great strides. The pilot plant is operating successfully and various operating conditions are being investi-

9) To be reproduced in document INFCIRC/88/Add.1.

10) GC(XI)/INF/97/Rev.1, Statement H.

gated, while an on-stream method of uranium analysis has been devised which, linked to a controller, provides fully automatic control of the extraction section.

5. The earlier studies of UO_2 and UF_4 production have had gratifying results and the latter project is now virtually at an end. Complete conversion of UO_2 and UF_4 at production rates of up to 40 lbs/hour has been obtained and the product has been shown to be suitable for conversion to UF_6 of nuclear grade with the possible exception of the molybdenum content. The pilot plant to study the Fluorox process for the manufacture of UF_6 from UF_4 using oxygen instead of fluorine as the reactant has now been completed.

6. The uranium metal plant — a pilot plant which has been on a production basis to produce fuel rods for a university sub-critical assembly — has also now completed its task. Various materials studies are in progress; they include the production of high-strength zirconium alloys and the development of ceramic fuels using relatively large sol-gel spheres and uranium carbide. The construction of a sodium mass-transfer loop is well advanced, and other work on sodium involves corrosion studies for which a high-temperature sodium facility incorporating the supply of ultra-high-purity argon is under construction. The local design, manufacture and commissioning of fuel capsule irradiation loops is a notable demonstration of the increasing sophistication of South African capabilities in relation to the nuclear industry.

7. The fascinating world of ultra-low-temperature metallurgy has now become accessible in South Africa with the construction of a liquid helium cryogenic loop, costing some $150 000, for the study of irradiation behaviour. Installation of the loop in the research reactor SAFARI 1 is currently being undertaken.

REACTOR PHYSICS

8. The critical assembly PELINDUNA-ZERO achieved criticality shortly before the end of 1967. As previously indicated this assembly will be used for reactor physics studies[11], and computer programmes have been written for the investigations being carried out with it and also with the sub-critical assembly which has now been modified and improved.

RADIATION STUDIES

9. A very much expanded field of research into gamma radiation effects has been opened up by the acquisition of an 18 000-curie radiation source. Hitherto work has been carried out with a 500-curie "hot spot".

11) Ibid., page 30, left-hand column.

RADIOISOTOPE PRODUCTION

10. The rate of radioisotope production has been doubled during recent months and it is now possible to undertake the chemical processing of certain isotopes, in addition to the production of a wide range of radioelements in the reactor. A further improvement in efficiency is being achieved by the direct coupling of the production facility building to the reactor by rabbit tubes, thus eliminating the manual transfer of materials between buildings.

HEALTH AND SAFETY

11. Activities relating to the safe handling of radioactive substances have resulted in the complete revision of the previous regulations for the use of these materials and the issue of a new code which is more practical in the light of current knowledge and practice. Studies of nuclear weapons fall-out in human bone structure have been intensified on account of the observed increase in fall-out. Fuller international collaboration in the Southern Hemisphere in these studies is being actively promoted and the results are being made available to international organizations.

REACTOR POWER

12. The additional plant and equipment needed to raise the thermal power of the reactor SAFARI 1 from 6 2/3 MW to the design figure of 20 MW has been installed and commissioned. The much intensified neutron flux will contribute greatly to the materials testing programme and also further speed the production of radioisotopes.

NUCLEAR PHYSICS

13. Apart from the continuation of work on the inelastic scattering of neutrons (on which an increasing number of publications will shortly appear), a great deal of effort culminated in the successful completion and commissioning of the second new terminal for the 3-MeV Van de Graaff accelerator at Pelindaba. Now operating smoothly, this terminal utilizes a pulse of one nanosecond at the different repetitive frequencies of 1, 3 or 9 megacycles per second, and permits improved energy resolution or alternatively increased productivitiy at the same energy resolution.

14. 1968 is effectively the last year of South Africa's second five-year programme of nuclear research. During these ten years the flow of results of value and interest to research workers in other lands has become progressively greater, and with the Republic poised to introduce a nuclear power programme, the years ahead offer wide scope for mutually beneficial co-operation in the application of nuclear energy between South Africa and her neighbours, especially the developing nations on the African continent.

25. SPAIN

Programmes put into Effect in the Peaceful Uses of Nuclear Energy 1967/68

GENERAL

1. During the period under review, the Junta de Energía Nuclear (Nuclear Energy Board — JEN) has made major progress in research and development programmes on the peaceful uses of nuclear energy, and private undertakings have likewise continued their work, now at a very advanced stage, on installations relating to the operation of several nuclear power stations.

FUEL CYCLE

Prospecting

2. Intensive efforts have been made to assess the potential of sedimentary formations of continental origin, chiefly Tertiary, and, in addition to these, Permotriassic and Lower Cretaceous outcrops. Scintillation equipment for aerial prospecting has been developed, and technical personnel have had to be trained to operate it. This has been carried out in collaboration with the Argentine Atomic Energy Commission. The new technique will be used to make a preliminary selection of sites in regions of the sedimentary type, which extend over large areas.

Mining

3. The amount of uranium ore mined was 115 600 m^3. At the end of the period under review the uranium reserves were estimated to be as follows: at prices less than 10 $/lb, 10 000 t of U_3O_8, classed as confirmed; in the price range 10-15 $/lb, 3600 t of U_3O_8 classed as confirmed, together with 27 000 t of additional resources; in the price range 15-30 $/lb, respectively 13 500 and 225 000 t of U_3O_8.

Ore processing

4. The study of bacterial leaching and uranium extraction using quaternary ammonium bases has continued, and the degradation of monazite sands for solubilizing uranium, thorium and rare earths has been investigated. Comparative tests have been made on a variety of leaching techniques and equipment, and there has been work on the chemistry of uranium extraction and re-extraction, recovery of uranium by ion exchange resins, and other related topics.

General Hernández Vidal uranium plant (Andújar)

5. This plant has continued to produce uranium concentrates at a rated output of 60 t of U_3O_8 per year, processing about 200 t of ore daily. The factory is situated in the province of Jaén, close to the ore deposits, and has been operating normally since 1959.

New uranium plant at Ciudad Rodrigo (Salamanca)

6. The Cabinet has recently given authorization for the establishment of this new plant, which will be able to process 1000 t of ore per day. The design, together with the preliminary technological trials, has been carried out by JEN at the Juan Vigon Centre in Madrid.

Fuel element fabrication

7. Prototypes of multiple-rod fuel elements based on natural UO_2 pellets, canned in aluminium and sintered aluminium powder (SAP), have been manufactured; the purpose of these fuels is to produce ^{239}Pu, which can then be used to start metallurgical studies of plutonium-bearing materials.

8. An investigation has also been carried out on the possibility of fabricating fuel elements from uranium recovered during reprocessing of depleted fuel from the JEN-1 reactor, so that an enrichment of approximately 15% can be maintained. There are now special welding techniques and instruments available for a precision study of deformation due to thermal recycling, radiation effects, or burn-up.

Irradiated fuel reprocessing

9. The M-1 plant, designed and built entirely by JEN engineers, has gone into service. It commenced operations with the reprocessing of JEN-1 reactor fuel, in which the ^{235}U is 20% depleted.

10. After the elements have been dismantled in the 1000-curie (Ci) hot cell, the can and fuel are dissolved in an acid medium; the solution is then put through an initial decontamination cycle with solvents, after which the uranium and plutonium are separated, and then repurified with further solvents. The maximum capacity of this reprocessing plant is 550 g of uranium per day.

Radioactive waste disposal plant

11. The CIES pilot plant for the decontamination and disposal of radioactive wastes is also now in service. The operations involved are ion exchange, evaporation and solidification. The plant contains a storage cell for high- and intermediate-level wastes, and the processing of the medium-level wastes includes evaporation and incorporation in asphalt for purposes of final disposal.

NUCLEAR REACTORS

JEN-1 and JEN-2 reactors

12. The JEN-1 reactor has been used for research in criticality, control rod calibration, neutron flux determination, raising the power, and so on. The relevant studies have also been made in connection with the proper functioning of the JEN-2 reactor. Reactor safety has been a subject of particular attention.

CORAL-1 experimental fast reactor

13. This zero-power reactor, the design, planning and instrumentation of which have been effected entirely by JEN, achieved criticality in March of this year. It consists of a core with 21 kg of uranium 93.5% enriched in ^{235}U, surrounded by a natural uranium reflector with no moderator. The core-reflector assembly is arranged in two halves, one of which lies on a moving carriage; the system is set in operation when the two halves are brought together.

14. The purpose of this reactor is to make a fast neutron source available for studying fast multiplicative structures, and also to gain experience in measuring fast neutrons.

RADIOACTIVE ISOTOPES

15. JEN has devoted considerable effort to the study of the production and use of radioisotopes and labelled compounds. In 1967, 2248 shipments were made, representing a total of 557.3 Ci, the bulk of which was produced by JEN. There are at present 446 users in Spain, and the number is on the increase.

16. Among the uses of isotopes promoted by JEN, mention should be made of the calculation of the flow rates of a number of rivers, the study of leakage from reservoirs, and research in plant physiology. JEN also operates the Náyade irradiation unit, which has a cobalt-60 source of 6900 Ci and is used to study the irradiation preservation of foodstuffs such as potatoes, lemons, and fruit juices.

MEDICINE AND RADIOLOGICAL PROTECTION

17. A great deal of experience has been gained in this field since the American air disaster at Palomares.

18. The JEN has acquired a whole-body counter and automatic batteries of counters for gross alpha measurements, with which it is possible to handle a large number of samples simultaneously.

19. In addition to routine monitoring activities, there has been research that will facilitate a more thorough understanding of environmental radioactivity and decontamination.

BASIC RESEARCH

20. JEN takes a keen interest in basic research, which it has performed to a large extent independently, but also on the basis of contracts with a number of Spanish universities; between 10 and 15% of the total budget is devoted to these activities.

21. In the field of physics, mention should be made of studies on elementary particle theory with particular emphasis on problems of higher symmetries and weak interactions; the propagation of pulsed neutrons in multiplicative and non-multiplicative systems; nuclear spectrometry of alpha, beta and gamma radiation; research on nuclear levels; absolute measurement of radioisotope activities; and experimental high-energy physics by analysis of bubble chamber photographs. A large part of this experimental work is being conducted in collaboration with the European Organization for Nuclear Research (CERN).

22. In the field of chemistry, mention should be made of radiochemical separation techniques, chemical behaviour of tracers, activation analysis with neutrons and charged particles, radiation chemistry, and the separation of stable isotopes by ion exchange chromatography.

23. In metallurgy, work has been done on the properties of solids at high temperatures and the effect of radiation on metals.

24. In biology, mention should be made of molecular changes in the replication of deoxyribonucleic acid (DNA) in normal processes, the action of nucleic acids on DNA synthesis in higher organisms, and study of the biological effects of low and very low doses of natural radiation.

TRAINING

25. The Institute of Nuclear Studies, a subsidiary organization of JEN, has continued to give a regular course in nuclear engineering for advanced graduates. It has also organized courses on the application of isotopes in industry, medicine, veterinary science, agriculture, and other fields, as well as other courses on specialized techniques such as instrumental chemical analysis.

26. Some of the universities and higher technical schools have held regular courses in nuclear science and engineering.

NUCLEAR POWER STATIONS

27. At the present time private industry in Spain is constructing three nuclear power plants, the first of which, the José Cabrera station, will go into operation towards the middle of 1968.

28. The three power stations are the one mentioned above, which embodies a pressurized-water reactor and has a capacity of 153 MW(e), the Santa María de Garoña station, of the boiling water reactor type, with a capacity of 440 MW(e), and the Vandellós station, with a gas-cooled reactor and a capacity of 480 MW(e).

29. In all three cases JEN has advised the undertakings concerned at various stages of the projects, and has rendered technical assistance on various subjects, chiefly concerned with nuclear safety. As advisory body to the Government, JEN has issued a large number of reports both on the equipping of the power stations under construction, and on their subsequent operation.

26. SWEDEN

Nuclear Energy Development in Sweden during 1967/68

1. The Swedish nuclear programme is making rapid progress. In 1969 the Marviken boiling heavy-water reactor (140 MW(e)) will be ready for operation with saturated steam. At present different systems of the station are being tested with light water, and heavy water is expected to be introduced into the reactor early in 1969. The Oskarshamn boiling light-water reactor (400 MW(e)) is due for commissioning during 1970.

2. In July 1968 the Swedish State Power Board ordered two reactors for the Ringhals nuclear power station on the Swedish west coast. The first reactor due to go into operation in 1973 will be built by ASEA; this is a boiling light-water reactor with an output of 760 MW(e). English Electric will manufacture the turbine. The second reactor is a pressurized light-water reactor designed by Westinghouse with an output of 809 MW(e). Components for this reactor will be delivered by the Swedish industrial group, Monitor, and the reactor will start operation in 1974. For this second plant the ASEA subsidiary, Stal-Laval, will deliver the turbine.

3. ASEA and the Swedish Government have decided to form a joint company, Aktiebolaget ASEA-ATOM, for independent industrial and commercial activities in the nuclear field. ASEA-ATOM will engage in the development, production and sale of nuclear reactors based on thermal reactor systems, components for such reactors, and nuclear fuel. The company will take over deliveries from AB Atomenergi and ASEA, including the first reactor for the Ringhals station. ASEA-ATOM will recruit its staff mainly from ASEA and AB Atomenergi. The new company will take over the fuel element plant of AB Atomenergi in Stockholm and the ASEA nuclear laboratory, as well as ASEA's fuel element plant.

4. As a result of the creation of ASEA-ATOM the activity of AB Atomenergi will in future be more centred upon research and development in the nuclear field and the work will be concentrated in the Studsvik research station, where already about 800 people are working. It is foreseen that the large thermal reactor programme in Sweden will continue to make considerable demands on the development resources of the Company but that a growing part of future development will relate to fast reactors.

5. During the year AB Atomenergi's uranium mill at Ranstad has operated at 3/7 of full capacity

(120 metric tons per year of uranium). The experience gained so far has been very good from the technical point of view and has also confirmed the cost analysis made during the pre-project stage. An economic and technical study is now being made for a plant having a capacity of about 500 metric tons per year.

6. For a couple of years efforts have been made to increase co-operation in the nuclear field between Denmark, Finland, Norway and Sweden. A report has now been published by the Nordic Contact Committee for Atomic Energy Questions regarding the possibility of extended nuclear power co-operation between the Nordic countries. The Committee stresses the need for an investigation of the role which nuclear power will play in the future supply of energy in the Nordic countries. A close collaboration between utilities and industries engaged in nuclear energy work is recommended. Furthermore, the Committee indicates the advantages of a rational co-operation between the Nordic nuclear research stations. Finally, the Governments are reminded that co-operation between governmental bodies in handling the safety of nuclear power stations is of common interest to all the Nordic countries.

27. SWITZERLAND

Progress Report on the Use of Nuclear Energy in 1967/68

ELECTRIC POWER GENERATION

1. Over the year under consideration the Swiss utilities have added a third nuclear power plant to their construction programme, which now stands as follows:

Power station	*Type of reactor*	*Electrical capacity (MW)*	*Start of construction*	*To be put into operation*
Beznau I	Pressurized water	350	1965	1969
II	Pressurized water	350	1968	1972
Mühleberg	Boiling water	306	1967	1971

In 1972, these three reactors, which are of the light-water variant, will be able to cover approximately 20% of Swiss electricity consumption.

2. Taking into account four other major projects under study, two of which involve foreign partnership, it can be stated that the Swiss utilities plan to meet future electric power requirements mainly on the basis of nuclear energy. In order to use this to the maximum advantage, they will also embark at a future stage on the construction of hydraulic pumping stations.

INDUSTRIAL ACTIVITIES

3. The industrial group which was interested in the development of a heavy-water moderated pressure-tube reactor successfully completed start-up tests on the experimental nuclear power plant at Lucens, and the latter was handed over to one of the electrical companies for operation on 9 May 1968. The operational programme, which is restricted to two years, is aimed at testing the performance of plant components and also provides for some experimental research.

4. The speed-up in plans for nuclear power generation in Switzerland has led this industrial group to discontinue its efforts to develop a heavy-water reactor and to concentrate on the design and manufacture of components for nuclear power plants, the demand for which on both Swiss and international markets is constantly growing. Swiss industry has thus been called upon to furnish an increasingly large part of the equipment for the three nuclear power stations being constructed in Switzerland, in addition to supplying a variety of important components for nuclear power plants abroad, as well as equipment for nuclear research centres. Furthermore, the first orders relating to the design and construction of such plants have been placed with Swiss engineering companies both by Swiss and foreign clients.

5. The project that was being worked on by a large Swiss industrial company for a 400 MW(e) nuclear power station based on a high-temperature

reactor is being continued in close collaboration with the joint programme operated by the European Nuclear Energy Agency (ENEA) at Winfrith (Great Britain) under the code-name "Dragon". This project will make it possible to decide within one or two years whether this system offers any clear-cut industrial or commercial advantages and, if so, will provide a basis for plans to build a prototype large power station.

REACTOR RESEARCH

6. Pursuant to the decisions previously adopted in the light of the new trend in power generation and industry, a long-term study programme geared towards the development of fast breeder reactors is now under consideration by the Swiss Federal Government; this programme could form part of a programme of international collaboration. As the first phase, a programme of work on a gas-cooled fast reactor has been undertaken by the Federal Institute for Reactor Research at Würenlingen in close collaboration with a large American firm. The results of this study, which also concern the possibility of converting the Lucens reactor into a fast-neutron fuel element irradiation rig, have been passed on to ENEA, which is currently seeking to determine what interest the European countries have in initiating another joint programme. The Institute has also drawn up a research programme on the possible use of plutonium as a fast reactor fuel, the first stage of which relates to the development and irradiation testing of plutonium carbide fuel.

7. During the past year the Federal Institute for Reactor Research celebrated the tenth anniversary of the start-up of its first facility, the Saphir swimming-pool reactor, and also began operation of a new experimental zero-power reactor designed to measure the reactivity of core components. The Institute's facilities have continued to provide services for research and university teaching, the production of isotopes for medical use, and a variety of other industrial purposes.

USE OF RADIATION

8. With regard to the industrial use of radiation, certain progress has again been noted over the period in question, thanks largely to the efforts made by the Swiss Association for Atomic Energy in publicizing information on the matter; establishment, within the private sector of the economy, of a Swiss Centre for Radioisotope and Radiation Techniques, with a range of activities covering all aspects of this field, has also been helpful in this respect. With a view to participating in an international programme organized by ENEA, a number of Swiss clock-making, chemical and mechanical-engineering firms interested in the study of nuclear batteries, have joined in an association for this purpose. With regard to the irradiation of food, the federal commission responsible for this matter has endeavoured to implement the research programme that it worked out earlier.

PROSPECTION FOR URANIUM DEPOSITS

9. In pursuance of a work programme drawn up by a committee of experts on Swiss uranium deposits, the major indications discovered so far have been subjected to renewed study. In the two mineralization zones examined, detailed surface, geological and radiometric analyses have shown that continued prospection at these two sites by sinking and drilling operations is justified.

BASIC RESEARCH

10. The Federal Institute of Technology and the cantonal universities continue to contribute actively to basic research in nuclear physics, in conjunction with the Swiss accelerators, and in particle physics, with the European Organization for Nuclear Research (CERN) accelerators, and also in fields related to nuclear energy. As regards the meson production unit, construction of which was agreed on last year, work on design of the resonance cavities and magnets for the 500 MeV high-intensity proton ring accelerator has produced very encouraging results, on the basis of which it is possible to go ahead with construction of the unit.

INTERNATIONAL RELATIONS

11. In addition to the bilateral agreements on co-operation between Switzerland and the United States of America, France, Canada and the United Kingdom of Great Britain and Northern Ireland, Switzerland now has agreements with the United States of Brazil and Sweden, although in the case of the latter ratification is still pending.

28. UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Advances in Nuclear Energy: 1967/68

INTRODUCTION

1. Nuclear power has become part of the British industrial scene — accepted by the public, fully competitive and contributing a significant and increasing proportion of electricity output. With its wide experience in the design, construction and operation of power reactors gained since the nuclear power programme began in the 1950's, UK industry is able to supply gas-cooled and water reactors for commercial power stations, together with complete fuel cycle services and a comprehensive range of nuclear components and equipment. To meet later needs, the United Kingdom Atomic Energy Authority (UKAEA) continues to press forward rapidly with the fast reactor.

2. This stage of development is being matched by plans for the future of the British nuclear industry. To equip the industry to meet the increasing demands that will be made upon it at home and from abroad, it is planned to concentrate the nuclear design resources of the various industrial organizations and UKAEA into two new companies. Thus, effective competition within the UK will be retained along with a more economical and efficient alignment of technological and industrial resources. It is also planned to create an independent nuclear fuel company from UKAEA's fuel production organization. The Government looks to the new arrangements to facilitate the forging of industrial links abroad, to which they attach great importance.

NUCLEAR POWER PROGRAMME

3. Nuclear power stations are making a significant contribution to the country's publicly-owned electricity generating systems. Oldbury, the eighth Mark I gas-cooled (MAGNOX) station in the first nuclear power programme, was to come on power in August. The performance of Hunterston 'A', which started operation in 1964, indicates the reliability of these stations. During the four winter months from November 1967 to February 1968 the average load factor was 102.8% of the designed output capacity. Over the year the load factor was 85.9% and the cumulative load factor since the station began operating has been 83%.

4. The second nuclear power programme based on the Mark II (AGR) gas-cooled system is making good progress, with three stations totalling 3700 MW(e) currently under construction at Dungeness 'B', Hinkley Point 'B' and Hunterston 'B', and others at the planning stage. The Minister of Power and the Secretary of State for Scotland have accepted the advice of the Nuclear Safety Advisory Committee that the safety of a gas-cooled reactor in a prestressed concrete pressure vessel is such that it may be constructed and operated much nearer built-up areas than hitherto permitted in the UK. Thus, nearly 200000 people are living within five miles of the site approved for construction of a Mark II reactor station at Seaton Carew near Hartlepool.

NUCLEAR FUEL SERVICES

5. The nuclear fuel services offered by UKAEA are available both to home generating boards and to customers overseas. A major current production effort at Springfields is the manufacture of Mark-I gas-cooled reactor (GCR) fuel elements. A plant for the production of UF_6 for enrichment plant feed is now operating there and large new plants for the production of oxide fuel will be commissioned in the near future. At Capenhurst separative work capacity is being expanded to meet the needs of the commercial Mark II gas-cooled reactors (AGR). The completion of the head-end plant at Windscale will add the capacity for reprocessing all types of low enriched uranium oxide fuel from home and overseas to the existing large capacity for reprocessing natural uranium metal fuel.

6. These developments enhance UKAEA's capability to provide a complete fuel service, which is already extensively used by a number of countries, and should lead to an expansion in its international trading in enriched uranium oxide, natural uranium fuel (including its reprocessing) and plutonium.

REACTOR DEVELOPMENT

7. The reactor development programme of UKAEA covers three main areas — gas-cooled reactors, the steam-generating heavy water reactor (SGHWR) and the fast reactor. In the gas-cooled field the immediate application arises for the Mark II reactor stations being built as part of the nuclear power programme. The development of a Mark III

gas-cooled reactor is being studied. A number of designs are being reviewed, all based on graphite-coated fuel particles of uranium dioxide or dicarbide, at a low enrichment.

8. One of the highlights of the year was the completion, on time and within the funds allocated, of the 100-MW(e) prototype enriched uranium SGHWR at Winfrith, which began generating electricity at the end of 1967. Measurements made during the commissioning of the reactor demonstrated that at full power the initial reactivity, nuclear power distribution, flow distribution and the influence of steam voids on reactivity were close to the predicted values. This light-water cooled, direct cycle, pressure tube reactor is one of the most advanced water reactors, providing at low capital cost an easily constructed reactor, simple to operate and maintain, and available in a wide range of commercial sizes. Development work on the enriched uranium version is continuing and is also going on, in collaboration with Australia and New Zealand, on a natural uranium SGHWR.

9. Construction of the 250-MW(e) prototype fast reactor (PFR) and the related development work has proceeded generally according to programme. Design work is in hand on a 1300-MW(e) fast reactor for large commercial generating stations, using a fuel sub-assembly almost identical to that of the prototype. The prototype itself will be used for irradiation experiments to produce the best possible fuel suitable for the first series of commercial fast reactors as well as to explore more advanced concepts.

10. The design of PFR is based on experience gained from the smaller Dounreay Fast Reactor (DFR) operated by UKAEA for several years. DFR was shut down at the end of July 1967 after a leak was found in its primary circuit, but went back on power in June 1968. The leak was due to a very small hole in some sub-standard welding which had, nevertheless, withstood many years of almost continuous operation of the reactor.

NUCLEAR DESALTING

11. UKAEA has published the results of extensive studies of large dual-purpose nuclear power desalination plants, with a detailed breakdown of their costs. The reactor systems chosen were AGR and SGHWR. The desalination plant designs were jointly developed for these studies with Weir Westgarth Limited.

12. Both reactor systems have two characteristics of special importance to dual-plant operation. The first is that they have high availability, leading to reliable supplies of low-cost water and electricity. The second is their inherent safety which is vital, particularly as the plant will have to be sited near population centres.

13. Within the current UK programme of research and development into methods of desalination of salt water for civil use, to be carried out at a cost of several million pounds by UKAEA, provision has been made for the continuing study of dual-purpose plant, including the updating of the commercial designs already prepared.

RADIOISOTOPES

14. The Radiochemical Centre has produced the important tracer isotope carbon-14 at isotopic abundances up to 99.5%, compared with levels hitherto available of 50 to 70%. Many labelled organic compounds have been prepared at these abundances, some by growing the green alga *Chlorella* with more than 90% of all its carbon substituted with carbon-14[12]. This advance has materially increased the usefulness of these compounds. Examples are in research into the mechanism of protein synthesis, the development of ultrasensitive methods of assay for enzymes and the accuracy of analysis for steroid hormones in urine and plasma, using a double tracer method.

NUCLEAR RESEARCH

15. With the advent of economic nuclear power, and pressure on the country's deployment of resources of skilled manpower and money in areas of advanced technology, some rationalisation is under way in nuclear research. UKAEA's underlying research, which provides background information and broad support to applied research and development, is to be reduced over the next two or three years to not more than 10% of UKAEA's total civil research and development effort. Expenditure on plasma physics and fusion research at Culham is expected to fall by 10% each year up to 1972. A rationalization of materials testing facilities will enable two research reactors to be closed down — BEPO later this year and the Dounreay Materials Testing Reactor (DMTR) in 1969.

16. A vigorous research programme will, however, remain, both in underlying areas and in the applied field where the emphasis will be on industrial applications of nuclear processes. Many of the major research facilities built at Harwell in the early days of the British atomic energy programme are now used to a significant extent by universities and other organizations.

12) The possibilities of this were first reported last year — see document GC(XI)/INF/97/Rev.1, Statement K, penultimate paragraph.

17. During the year much new information has been gained on the properties of materials, including the effects of irradiation upon them and in consequence their use in reactors. The availability of modified and new equipment, including the Variable Energy Cyclotron and the Harwell "refrigerator" producing temperature down to 0.1°K, has greatly extended the range of these studies.

18. In the industrial application of nuclear processes, the Activation Analysis Service run by Wantage has been extended. Another four gamma-irradiation plants were built by UKAEA licensees to meet overseas orders and are now in operation for treating medical equipment or food. Gamma radiation from cobalt-60 is being used for the commercial production of wood-plastic composites. Advances in electron-beam curing of paints have led to the construction at Wantage of a pilot commercial installation for the ultrarapid cold-curing of industrial paints.

19. The isotope-heated thermoelectric generators, RIPPLE I and II, have operated continuously and completely unattended since first put into operation in navigational beacons in 1965.

20. Measuring techniques involving the use of radioactive isotopes as tracers have been developed and are being used for research into hydrological and ground-water problems of national importance. Isotope measuring techniques have proved extremely accurate for measuring large turbulent flows, as in the cooling water systems of power stations.

21. Work has continued on plasma physics and fusion at Culham Laboratory. Theoretical methods have been advanced for investigating the stability of plasma confinement in practical configurations. The present generation of confinement experiments has provided valuable data which are being used in the design of the new series of stellarator and multipole experiments now being commissioned.

INTERNATIONAL COLLABORATION

22. The UK has continued to collaborate internationally in the development of the peaceful uses of atomic energy, both through the various multilateral agencies and under bilateral agreements with other countries. In general, these intergovernmental agreements provide for exchange of information and for the supply of nuclear material, equipment and facilities under safeguards. The UK has signed new agreements with Finland and Japan during the year, and is ready to negotiate agreements with other countries, where this is considered necessary to facilitate collaboration in the peaceful uses of atomic energy.

23. UKAEA has remained in contact with Atomic Energy Commissions, public utilities and industrial concerns in many parts of the world and now has formal collaborative agreements with organizations in 15 countries.

TRANSPORT REGULATIONS

24. All movements of nuclear material within the UK and from the UK to overseas countries are made in full conformity with the Agency's Regulations for the Safe Transport of Radioactive Materials. The codification in the latest edition of the Regulations[13] of the requirements for "large source" traffic has made a valuable practical contribution towards facilitating the movements of irradiated fuel from overseas to the UK.

13) Safety Series No.6, 1967 Edition (STI/PUB/148).

29. VIET-NAM

Progress in the Peaceful Uses of Atomic Energy

1. The escalation of the war during the past year directly affected our scientific and technical potential. In the nuclear research field, budget and staff reductions seriously curtailed the activities of the Viet-Namese Atomic Energy Bureau. In spite of that, the Dalat Nuclear Research Centre has been able to carry out a number of research projects of practical value.

2. The Radiobiology Department has concentrated its efforts on studying the radiation sensitivity of rice and the muong bean and investigating soil fertility by means of radioisotopes.

3. The technical and economic aspects of rice preservation by gamma irradiation have been considered, and with the acquisition of a sufficiently powerful gamma radiation source, Viet-Nam hopes to be able to set up a pilot centre in the near future.

4. In the animal biology field, study of the effect of low gamma-radiation doses upon the incubation period of hens' eggs has produced interesting results.

5. With the assistance of the Dalat Pasteur Institute and the Isotopes Laboratory at the Cho Ray Hospital, biological tests have been performed on samples of medically applied iodine-131 and colloidal gold-198, prepared by the Dalat Nuclear Research Centre.

6. Apart from producing these two radioisotopes used for diagnosing thyroid gland and liver diseases, the Radiochemistry Department regularly supplies the Radiobiology Department and the Radioisotopes Laboratory of the Ministry of Agriculture with phosphorus-32 for agricultural research. Methods for preparing sulphur-35, fluorine-18, copper-64 and technetium-99m have also been developed.

7. Activation analysis forms a not less important part of the activities of the Nuclear Research Centre. In 1967 various neutron activation analyses were carried out, such as determining traces of copper and zinc in hevea leaves, arsenic in locally produced soya sauce and so on.

8. In the field of nuclear physics, the question of radionuclide standardization has been of particular interest to the physicists of the Dalat Centre. In collaboration with the Electronics Department, the Physics Department has constructed a Rossi coincidence circuit with a resolving time of 3 μsec. The availability of a beta-gamma and gamma-gamma coincidence circuit has made it possible to measure the radioactivity of a number of radionuclides with a simple decay diagram (^{198}Au, ^{60}Co, etc.).

9. The bibliographical study of nuclear spectroscopy, initially prompted by Dr. Y.Y. Chu, an expert of the IAEA, is progressing satisfactorily, but the intended project for calibrating and standardizing short-lived radionuclides has not yet got under way, for lack of equipment.

10. The mechanism of nuclear reactions has also been studied and certain problems of mathematical physics have been resolved by the Fortran method, using the IBM-1401 computer of the Ministry of Finance, Saigon.

11. In the radiation protection field, apart from the routine monitoring of environmental radioactivity, a dosimetry service using films has been set up for the benefit of all people in the country using atomic radiation sources. Systematic inspection of all public and private bodies using sources of this type was started at the beginning of 1967, and so far 50 institutions have been surveyed and placed under the supervision of the National Commission for Protection against Atomic Radiation.

12. Two booklets written in Viet-Namese and entitled "The Safe Use of Radioisotopes" and "Recommendations on the Use of X-rays" have been widely distributed by the Atomic Energy Bureau.

13. A two-week course was organized in 1967 to initiate X-ray equipment operators in radiological protection techniques.

14. In the field of nuclear science education, the Atomic Energy Bureau, in collaboration with the Agricultural Research Commission, has organized a training course on the application of radioisotopes and radiation in agriculture.

15. In order to facilitate the spread of nuclear information and education in nuclear sciences, the Atomic Energy Bureau has published a vocabulary of nuclear terms in Viet-Namese. Furthermore, a French-Viet-Namese nuclear dictionary is being prepared. These documents will certainly be useful

for students intending to read for the Certificate of Nuclear Physics which was recently instituted at the Faculty of Sciences, Saigon.

16. Finally, the popularization of nuclear sciences and techniques continues to hold an important place in our work programme. The Atomic Energy Bureau has continued to publish a large number of popular booklets. Public lectures have been held. In particular, two important lectures followed by the showing of the film "The Nuclear Challenge", kindly placed at our disposal by the IAEA, were given by two IAEA experts; one on International Co-operation in the Peaceful Applications of the Atom (Dr. Ha Vinh Phuong), and the other on Use of Radioisotopes and Radiation in Agricultural Research (Doctor I.G. Valencia).

30. YUGOSLAVIA

Progress in Scientific Research on and Peaceful Applications of Nuclear Energy in 1967/68

INTRODUCTION

1. Scientific research in the field of nuclear energy is pursued in six specialized nuclear institutes and in other research laboratories set up at University centres and industrial enterprises. It is being conducted in the fundamental, applied and development branches.

2. Fundamental research embraces physics, chemistry, radiobiology and electronics.

3. Applied research covers the production of radioisotopes and labelled compounds and their application in industry, hydrology, agriculture, forestry, veterinary and human medicine, and in other fields of research.

4. Development research is being pursued on the prospection and exploitation of nuclear raw materials, and the technology of their processing; on problems close to nuclear power, i.e. problems associated with the technology and metallurgy of fuel and fuel elements, reactor heat transfer, reactor physics and electronic equipment for the operation, control and exploitation of nuclear reactors; further, on problems concerning the design, siting and safety of nuclear power stations, the industrial manufacture of some nuclear power plant components and physical and medical protection against ionizing radiations.

5. These scientific activities absorb today 1000 scientists and engineers, of whom 240 have the title of Doctor of Science.

FUNDAMENTAL RESEARCH

6. In nuclear physics theoretical and experimental investigations are being conducted in the field of low-energy physics, solid-state physics, physics of ionized gases and quantum electronics. In high-energy physics only theoretical work is being done. In low-energy physics activities are centred around the development of antilinear algebra and the three-body interaction. In beta-gamma spectroscopy past work has enabled commencement of investigations into electrostatic fields and the influence of the chemical nature of compounds upon the binding energy of electrons, while the study of the technique of perturbed gamma correlations has opened up investigations into the inner structure of garnet-type material and intermetal compounds.

7. In research into nuclear reactions it is worthwhile to point out the results obtained in the understanding of the reactions obtained by bombarding neutron-rich helium isotopes, and the technique of the measurement of short-lived isotopes obtained by 14 MeV neutron activation. Further, work has been done on nuclear models; on electromagnetic and beta radiation; on the study of systems with small numbers of nucleons; and on nuclear-nuclear interactions; and in fast neutron physics, particularly on nuclear spectroscopy of the reaction mechanism

8. In solid-state physics experimental and theoretical investigations have been carried out into the magnetic, ferroelectric, optic, semi-conducting and structural properties of solid bodies (uranium oxides and sulphides, pyrolytic graphite, substances of the KH_2PO_4 type). Research has also been done into the diffusion of copper and sodium in germanium and silicon microcrystals, the resonant scattering of gamma radiation, gamma-gamma correlation and Compton scattering.

9. In ion physics research has been done in atomic collision processes in the gaseous and solid stage, and in the dynamics of electric gaseous discharges. An apparatus has been developed for the testing of the process in the 5-50 keV range.

10. In quantum electronics work has been done on laser beams in various environments.

11. Research in nuclear chemistry covered basic research of interest for nuclear technology; study of reactions interesting for the safe handling of nuclear fuels; development of methods for the reprocessing of fuel (including a further advancement of the Purex process); study of the physico-chemical changes under the action of radiation; the fundamental aspects of liquid-liquid extraction; and development of analytical methods of control.

12. In this field modern physico-chemical methods have been developed and work is being done on activation analysis, the chemistry of complex compounds and the development of electro-chemical reduction by the use of a rotating mercury electrode. Theoretical investigations are focused on the study of the electronic structure of complexes and organic systems, as well as on molecular spectroscopy.

13. Research in radiobiology and fundamental biology included the physiological and biochemical changes in the central nervous system under conditions of irradiation; radiation haematology; the effects of radiation upon the genetic regulatory systems; the genetic effects of radiation; the hypophysis-hypothalamus-gonad feed-back; metabolism of the build-up and function of nucleic acids and the effect of radiation on them; and radiation immunology. In addition, radioecological research has been done in the northern part of the Adriatic Sea and in the water-stream of the river Danube.

14. Research in electronics has been conducted to help solve the problems of electronic instruments for nuclear and other investigations, particularly for physics, chemistry and biology. The research has been in three directions:

(a) Study of the development of equipment and systems using digital electronics for the processing of data obtained by measurements; theoretical and experimental development of digital electronic assemblies, logic and systems;

(b) Study of the sensitivity of the measuring methods of electronic equipment, particularly in connection with the problems of the construction and operation of nuclear magnetic resonance spectrometers and analysers, problems of the identification of weak signals in the presence of noise, analogue digital conversion and oscillators; and

(c) Research into measurement methods and the development of high resolution electronic assemblies. The programme includes theoretical and experimental work on assemblies for amplification, filtration, amplitude discrimination and the counting of pulses from the radiation detector, and on the primary processing of pulses for time analysis.

APPLIED RESEARCH

15. Applied research is being conducted in the production and application of radioisotopes and labelled compounds. Apart from normal production of radioisotopes, which in 1967 amounted to 9400 curies (Ci), contained in 1480 items, work has been done on the further extension of the range produced and on improvement of the quality of the products. Mention may be made of the new products for medical applications—the iodine-labelled compounds hippuran, rose-bengal and serum albumin. The production continued of strong teletherapy radiation sources (2000 Ci Co).

16. The application of radioisotopes increasingly finds its place in industry, hydrology and medicine, while in agriculture radioisotopes are being used more for research purposes in the agricultural institutes.

17. At the Institute for the Application of Nuclear Energy in Agriculture, Veterinary Medicine and Forestry at Zemun, a United Nations Special Fund project (UNSF) entitled "Nuclear Research and Training in Agriculture" has been successfully accomplished. The aim of this project was the improvement of agricultural production by the introduction, development and general application of nuclear research techniques. The executing agencies were the Agency, on behalf of UNSF, and the Federal Nuclear Energy Commission, on behalf of the Yugoslav Government. At present, intensive work on current problems of Yugoslav agriculture is being carried out at the Institute. At the same time wide international collaboration is also being achieved.

DEVELOPMENT RESEARCH

18. This research concerns problems associated with the development and preparations for the building of a nuclear power system, and with activities on radiation protection. In this field the research centres have developed methods and techniques enabling the direct development and manufacture of some parts of nuclear equipment, materials and power-plant fuel to be launched.

19. Work on the location of nuclear raw materials started in 1948, beginning with uranium prospection in certain types of terrain. Detailed studies have already been completed, as well as regional pro-

spection of an area covering some 50 000 km^2 where investigations have shown that there exist favourable conditions for the occurrence of uranium and for mining exploration.

20. Investigations have revealed a vast number of radioactive anomalies, low-grade uranium deposits and two deposits with uranium concentrations of economic value. The results obtained and the identified amounts of uranium provide a basis for the further conduct of regional prospection over an area covering some 40 000 km^2, where one can expect that an increase in the raw material resources of economic value will be discovered by further exploration.

21. In the processing of domestic nuclear raw materials research is being conducted on the selection and development of the necessary technological processes, as well as on the production of uranium concentrate, nuclear grade uranium oxide and nuclear grade uranium metal for reactor fuel. Besides, processes are being developed for the production of nuclear grade structural and alloying reactor materials, such as zirconium, niobium and molybdenum.

22. Research is being done on the laboratory and pilot-plant scale. The technology of the production of uranium dioxide and uranium metal, the quality of which meets the required standards, has been mastered.

23. In hydrometallurgy good experience has been gained in the application of organic solvents and solid ion-exchangers, reduction and fluorination.

24. In the development of UO_2 fuel elements research has been conducted on powder characterization, elaboration of the method for the chemical activation of powders and sintering, which has enabled the problems associated with the production of these fuels to be solved. Results have been obtained in the field of nuclear, physical and heat transfer testing of fuel elements through the use of a high-pressure out-of-pile reactor loop. Work in this field covers also research on the development of a fuel element assembly and of new methods for the production of ceramic fuel by vibratory compaction. Arrangements have been made for the irradiation of fuel elements in the RA reactor[14], while further work on radiation damage will be handled through international co-operation.

25. Research on the characteristics of boiling heavy-water reactors has led to the advancement of reactor calculation methods for use by the designers. Experimental research in heavy-water reactor physics develops under the NPY project[15]. Experimental facilities have been developed for testing the thermal properties of concrete vessels for these reactors. Activities connected with the development of advanced reactor systems embrace research on heat transfer and nuclear-thermal reactor calculations with integral steam superheat, the development of uranium metal fuels and their use in heavy-water systems, and the development of prospective fuels of the UO_2-PuO_2 type.

26. Research on domestic production of ancillary systems for nuclear power plants has been concerned with liquid radioactive effluents and their decontamination, primary circuit water, radioactive gases and aerosols, and the disposal of radioactive effluents into river-streams.

27. Work on reactor electronics and instrumentation covers the development of the system and components of digital operation, data processing research in fast electronics and the application of unipolar transistors to the construction of isolated gates. Research in reactor electronics has resulted in the development of some specialized equipment for research activities and for use in industry and power development.

28. In connection with radiation protection and nuclear reactor safety the following have been developed: methods and instrumentation for radiation field dosimetry, individual dosimetry, the detection of radioactive gases and aerosols, measurement of the contamination of the biosphere and the processing of radioactive materials; methods for the decontamination of equipment and for internal and external human decontamination; studies of the mechanisms of the action of radiation upon living organisms, and analyses of potential accidents and their effects.

29. The Yugoslav industrial and design organizations carry on research activities to enable domestic industry to build nuclear power plants. Thus, in addition to studies concerning the most feasible power plant types and sizes, attention has been devoted to investigations of the technology for manufacturing large stainless steel and prestressed concrete reactor vessels, to the development of fuel loading machines, to the development of a control rod system of original design and to the testing of the corrosion of reactor vessels and piping materials. The electricity utility organizations are carrying on economic studies related to the integration of the first nuclear power plant of 400-500 MW(e) into the national grid.

14) The 6.5 MW(e) research reactor at the Boris Kidrič Nuclear Institute, Vinča.

15) This project is the subject of the agreements reproduced in documents INFCIRC/55 and Add.1.

30. The Yugoslav Nuclear Energy Commission maintains connections and co-operation with numerous national atomic energy commissions and the International Atomic Energy Agency, the European Organization for Nuclear Research, etc., and the nuclear institutes do the same with many nuclear centres and other scientific institutions in various countries. Besides, wide exchange of experience and co-operation is being maintained, through participation in numerous international symposia and seminars, the publication and exchange of published scientific papers, the placement of foreign trainees in the nuclear institutes and the joint work of groups of researchers. Joint programmes are being undertaken with some countries, the total cost being shared.

31. The nuclear institutes have the following research facilities and equipment: a 6.5 MW(th) heavy-water research reactor with a 6.10^{13} n/cm^2 sec neutron flux; a zero-power reactor; a 250-kW TRIGA reactor; a 1.5-MeV Cockcroft-Walton accelerator; a 16-MeV cyclotron; a 2-MeV Van de Graaff generator; a 31-MeV betatron; three neutron generators of 220 keV each; a ^{60}Co radiation unit of 3500, 1000 and 300 Ci; digital and analogue computers and other important equipment.